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GEOPHYSICAL INVESTIGATION OF ROTORUA

By N. MODRINIAK, Geological Survey, Department of Scientific and Industrial Research

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Summary

The magnetic properties of Rotorua District were investigated. Inferences were drawn from analyses of geophysical observations in relation to geological structures controlling Rotorua depression. The subsidence-theory of the origin of Lake Rotorua is supported. The existence of a fundamental fault fracture between Whakarewarewa and Ohinemutu is inferred and the extension of the sinuous Horohoro fault northward suggested. Resistivity and spontaneous polarization measurements are discussed. The use of thermal mud in the construction of acid-resisting pipes is suggested, and an improved method for the utilization of natural heat recorded.

INTRODUCTION

THE surface thermal activity at Rotorua is due to a deep-seated source beyond visual observation. When the elucidation of its origin was attempted in the past, inferences had to be drawn from qualitative and quantitative analyses of thermal springs. Similiar inferences from the analyses of geophysical data in relation to structures fundamentally controlling the Rotorua depression are presented in this paper.

Magnetic and electric methods were applied to this study. The area selected is situated to the east and south of Lake Rotorua, and covers approximately sixteen square miles, most of it being occupied by Pleistocene lake beds, completely screening structural features below. Prior to this investigation, W. M. Jones (1) observed the vertical magnetic field in the Ohinemutu-Rotorua Area and C. N. Watson-Munro (2) at Whakarewarewa and Tikitere.

The recorded history of thermal activity at Rotorua is disjointed. Observations in the past were not continuous, and no basis was provided for comparison with present-day observations. The recent establishment of the Vulcanological Observatory will do much to rectify this omission. Attempts to develop thermal resources have focussed attention on a great mainly undeveloped asset.

The area so far investigated by geophysical means at Rotorua represents only a minor portion of the extensive thermal belt of New Zealand. This whole belt of country offers a wide field of investigation and is likely to reward the effort with valuable scientific and economic data.

MAGNETIC OBSERVATIONS

The magnetic elements at Rotorua observed during 1943 are as follows :—

Vertical Force (Z) 50,103 gamma
Horizontal Force (H) 25,181 gamma
Total Force (F) 56,107 gamma
Declination (D) 16° 26′ E.
Inclination (I) -63° 19′
X component, along geographical meridian, 24,158 gamma
Y component, perpendicular to geographical meridian, 710 gamma

The values for (H), (D) and (I) were supplied by the Magnetic Observatory, Christchurch. The observations were made on the Motutara Golf Links at the Geophysical Base (B1). It is a permanent base, anchored to the soil by a concrete slab and copper rod. The original base of Farr and the one more recently used by Parkinson and Baird are in a rather magnetically-disturbed area. Jones has previously pointed out their shortcomings. Subsidiary bases were also laid out. Of primary importance is the sub-base (B2) situated in Kuirau Park. Its observation in conjunction with those of the main base permitted a close check on the general performance of the instrument used. Its value is (B1) –175 gamma correct to + 5 gamma at a temperature of 15°C. Of interest are the comparative values for the magnetic survey stations at Atiamuri, Taupo, Tokaanu and Turangi. Assuming Rotorua base value to be zero, the comparative values for Z are as follows :

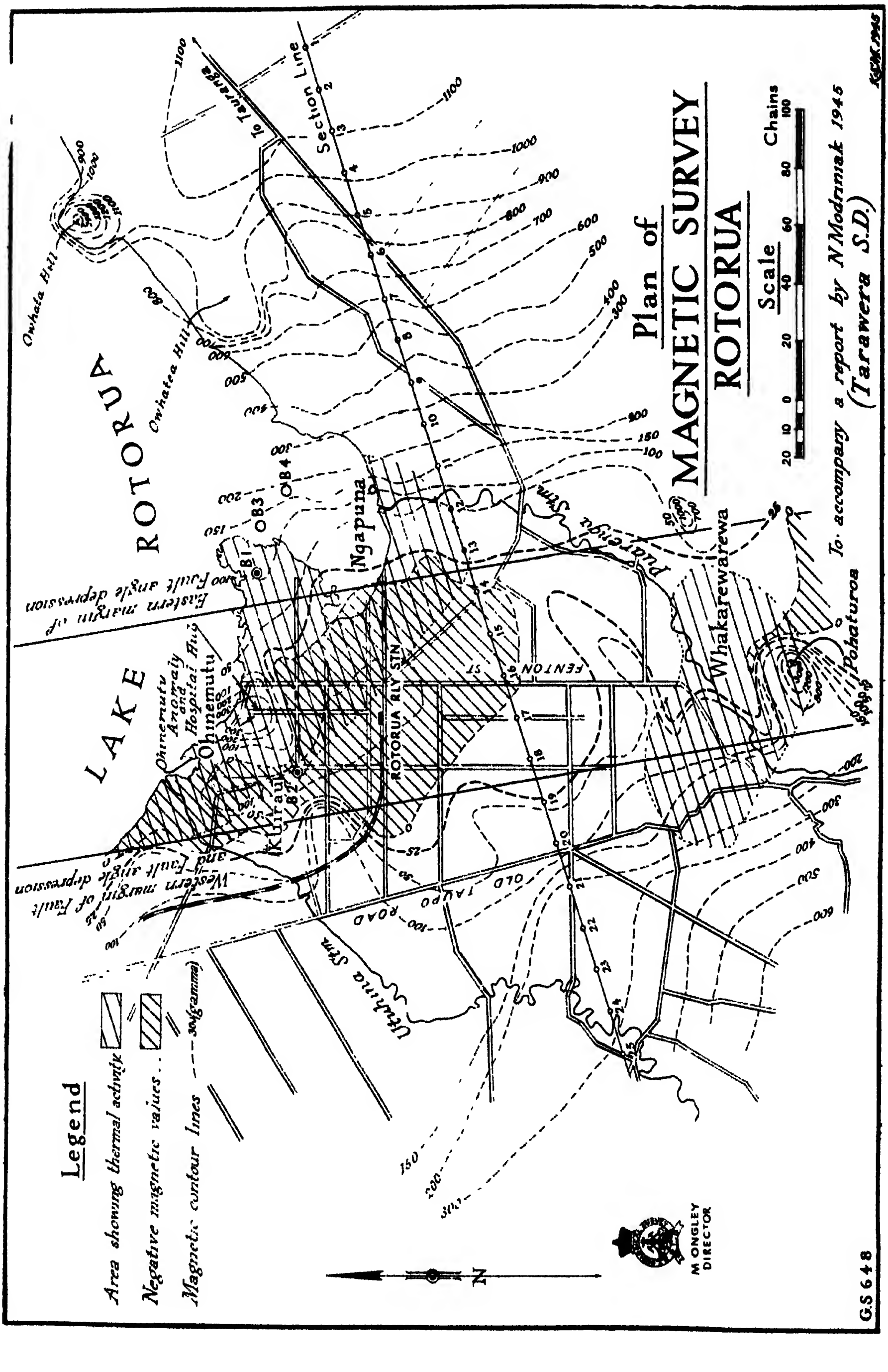
Atiamuri	827	gamma
Taupo	1093	,,
Tokaanu	1044	,,
Turangi	1010	,,

The scale value of the instrument used was determined over a period of two years. Its average value was 26 gamma per scale division at a temperature of 15°C. The temperature coefficient of the instrument was determined as 0.2 scale divisions per 1°C for the scale value of 26 gamma. Latitudinal corrections amounted to 13 gamma per mile south. Individual observations were corrected for temperature and diurnal variation, and reduced to the normal value of the locality, which is taken as 49,904 gamma and corresponds with the Zero value of the magnetic map. The diurnal variation amounted to approximately 12-16 gamma per day.

THE MAGNETIC MAP

Field work was completed with the preparation of the magnetic map (Fig. 1). It covers an area of approximately 16 square miles and includes the township of Rotorua. The magnetic observations are presented in the usual manner. Lines of equal intensity of the vertical magnetic force are drawn at intervals of 100 gamma, and closer where needed. The reduced magnetic map shows the departure from magnetic normality, and is therefore, a function of the surface and sub-surface distribution of magnetic material in this locality.

Elements that enter into the interpretation of observed magnetic values are the original magnetization of the igneous rocks, and the effect of chemical actions and vulcanic heat on the magnetic properties of ferro-magnetic minerals. The total magnetization results from two factors, namely the induced magnetization by the present earth-field


Plan of
MAGNETIC SURVEY
ROTORUA
Scale
Chains
To accompany a report by N Modriniak 1945
(Tarawera S.D.)
Legend
Area showing thermal activity
Negative magnetic values
Magnetic contour lines
LAKE
ROTORUA
Section Line
To Tauranga
Owhatea Hill
Eastern margin of Fault angle depression
Western margin of Fault angle depression
Ohinemutu Anomaly and Hospital Fault
Ohinemutu
Kuirau
Ngapuna
ROTORUA RLY STN
FENTON ST
OLD TAUPO ROAD
Utuhina Stm
Puarenga Stm
Whakarewarewa
Pohaturoa
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DIRECTOR
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FIG. 1

acting on material of a given susceptibility, and the remnant magnetization that the rock may have retained from a previous state of magnetization. Several ways are open to the investigator to determine magnetic susceptibility. It can be inferred from published susceptibility measurements of similar rocks elsewhere, by measurements in the laboratory, or by determining the content of magnetite as volume per cent. Schlichter's method of determining the volume per cent. of magnetite in geological specimens was attempted. Magnetite is the dominant magnetic mineral in igneous rock, and within reasonable limits, the magnetic property of a rock is proportional to the volume per cent. of magnetite. When in a highly disseminated form, as it occurs in rocks, its effective susceptibility in the earth's magnetic field is approximately 300,000. 10^{-6} c.g.s. Accordingly the susceptibility of a rock can be estimated by multiplying this value by the volume per cent. of the disseminated magnetite. The magnetite content in volume per cent. of Patetere ignimbrite was determined in a low magnetic field and approximate values were obtained that varied between 0.8 to 1.8 v.p.c. representing a mean value of 1.3 v.p.c. The effective susceptibility would consequently be of the order of $3{,}900.10^{-6}$ c.g.s. and at Rotorua where the earth's field is of the order of 0.56 oersted the total magnetization is $3{,}900.10^{-6}$. $0.56 + IP$ or $0.00218 + IP$. The term for permanent magnetization (IP) is difficult to determine. Koenigsberger pointed out that owing to special circumstances some lavas have permanent magnetization in excess of induced. The same may apply to ignimbrites, for instance, that were deposited at a temperature of approximately 1000°c. and consequently must have obtained their magnetization while cooling in a magnetic field that may have been different from the present.

Watson-Munro (2) found the susceptibility of one sample of ignimbrite from Mamaku to be $9.5.10^{-4}$, (in a field of approximately 600 gauss) which was only 5 per cent. lower than for a specimen of Ngongotaha (Patetere) rhyolite. He realized that the values would not be the same for the earth's field of less than 1 gauss but considered that the proportions of the susceptibilities of different rocks in other fields higher than 600 gauss to be sufficiently constant to justify the assumption that these proportions could be used for comparisons in the earth's field. The sheet rhyolitic material at Waihi and Waitekauri appeared to Jones (1) considerably less magnetic than this Mamaku sample, though the position is complicated there by the andesites which underlie or adjoin the rhyolite. His conclusion was supported by susceptibility measurements made at the Magnetic Observatory, Christchurch, in a field of ca. 30 gauss, as follows :—

Tridymite rhyolite	$0.7.10^{-4}$
Wilsonite	$0.8.10^{-4}$
Tridymite rhyolite	$0.3.10^{-4}$

As these were made in fields of the order of 30 gauss, the corresponding values for the higher field of 600 gauss would be even less.

These values are all much less than that of Watson-Munro for the Mamaku ignimbrite, even though the Wilsonite specimen contained fragments of andesite. The differences certainly call attention to the need for more detailed investigations of the variability of magnetic properties in the ignimbrites. Watson-Munro (2) found the domes of Ngongotaha and Haparangi to give vertical anomalies of up to 2000 gammas. The writer observed in the Whakamaru area maximum values of 1,500 gammas on similar rocks.

Measurements of susceptibility of sediments are even less satisfactory than for the igneous rocks. Field observations indicate however the existence of a wide susceptibility difference between the igneous rocks and the sediments at Rotorua, so that the inference that the magnetic observations were made on a non-magnetic medium resting on a magnetic medium is justified. Susceptibility measurements on geological specimens are essential to an analytical approach to the interpretation of magnetic data. Not before a geophysical laboratory is established will it be possible to attach to various rock members their appropriate magnetic significance.

The already complex nature of the magnetic properties at Rotorua is further complicated by thermal action on the ferro-magnetic minerals and by the effect of heat. From drilling information it can be shown that the thermal gradient to a depth of 200-300 ft. is of the order of 1° c. for every two feet of depth in thermally active areas. At this rate the Curie Point would be reached at a depth of approximately 1,000 ft. and the rocks would become non-magnetic. The thermal chemical destruction of magnetite would result in the formation of much less magnetic iron compounds. Chemical analyses of a few specimens of rocks at Rotorua indicate in ignimbrite an average iron oxide content of 2.08 per cent., Patetere rhyolite 1.73 per cent. and Haparangi rhyolites 2.02 per cent. (Grange (4)).

INTERPRETATION OF MAGNETIC DATA

Calculation of magnetic anomalies for simple geometric forms, such as ellipsoids of rotation, infinite cylinders and spheres are available and, although masses in nature are never spherical or cylindrical, surprisingly close estimates can be made on the basis of this assumption. The Ohinemutu anomaly, isolated from the areal magnetic pattern lends itself to this method of interpretation. Areal anomalies are more difficult to interpret as the calculation of the shape and size of the magnetic mass from the measured observations is more complex. A semi-graphical method suggested by Haalck (3) appears practical. Although limited in its application it is valuable in conjunction with other geophysical methods. The graphical part consists of a diagram representing a vertical section along a line of symmetry. Each of the rectangles into which each graph is divided represents the vertical cross-section of a prism of infinite length at right angles to the plane of the section. Each cross-section of each prism is calculated to produce a predetermined gradient. By plotting a cross-section of an assumed structure and superimposing it on the graph, a number of squares are covered for a given position. The squares are then counted and their algebraic sum multiplied by the magnetic contrast will indicate the magnitude of the component. The magnetic contrast is the difference of susceptibility between the magnetic medium and its surrounding medium. The assumed profile is then altered till the theoretical and practical values agree. The section thus obtained for the areal anomaly at Rotorua was used as the basis for further calculations (Fig. 2).

The Ohinemutu anomaly (Fig. 1) forms an isolated unit within the areal magnetic pattern. The negative anomalies form its western flank, while to the east it merges with the areal magnetic contours. The surface outcrops on Hospital Hill are not of material which would account for the magnetic anomaly. A specimen obtained from Hospital Hill

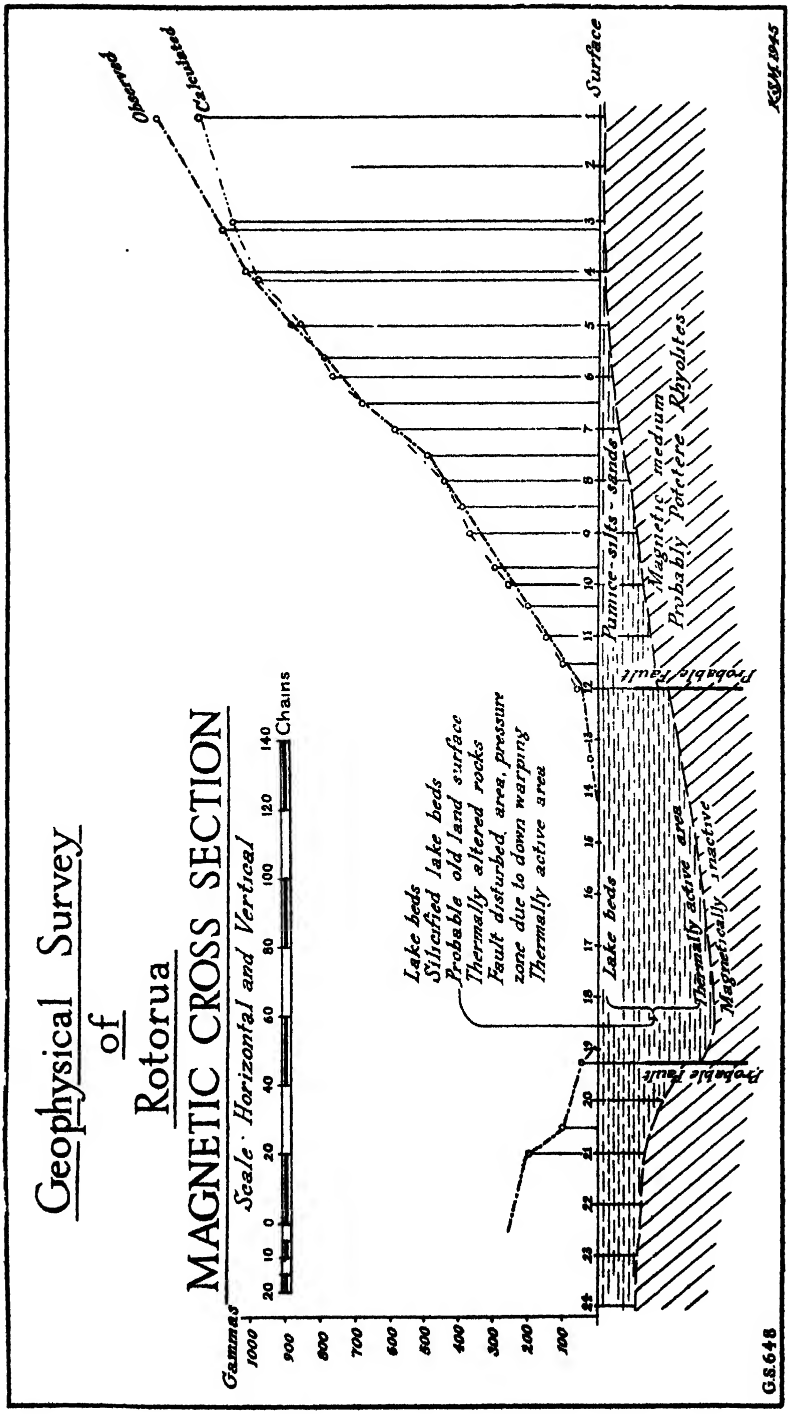

Geophysical Survey
of
Rotorua
MAGNETIC CROSS SECTION
Scale: Horizontal and Vertical
Chains
Gammas
Observed
Calculated
Surface
Pumice-silts-sands
Magnetic medium
Probably Poretere Rhyolites
Probable Fault
Lake beds
Silicified lake beds
Probable old land surface
Thermally altered rocks
Fault disturbed area, pressure
zone due to down warping
Thermally active area
Thermally active area
Magnetically inactive
Probable Fault
K.S.M. 1945
G.S.648

FIG. 2

was studied by C. O. Hutton, who was unable to determine its original nature owing to the advanced state of thermal decomposition and subsequent opalization. Owing to the presence of curious lenticular patches in the opal mesostasis, it is possible that these patches represent original pumice material. The rock specimen could almost be regarded as non-magnetic, as only 0.5 volume per cent. of magnetic material was separated in a strong magnetic field. Jones (1) however found what appeared to be decomposed spherulitic rhyolite in a cutting in Rangiuru Street, and attributes the anomaly to a small dome of rhyolite, much of it perhaps still hot and under-going thermal alteration.

The magnetic field from a vertical cylinder is similar to the anomaly observed at Ohinemutu. The upper surface of the postulated cylinder has a radius of the order of 500 ft. and is at a depth of the order of 100 ft. or less. When substituting the geometric form for the magnetic body it is expedient to assume vertical magnetization and the replacement of volume magnetization by surface magnetization of the upper and lower surfaces. A reasonably accurate approximation to the magnetic field of the assumed cylindrical form may be obtained by the use of solid angles (5). A positive anomaly will be produced over the centre of the body, and its maximum is reached when the cylinder extends to infinite depth Finite depth gives rise to negative values at points where the solid angles subtended by the lower surface will be greater than by the upper disc.

Only the western portion of the Ohinemutu anomaly was considered. The recorded values of vertical anomaly for different values of X, the distance from the centre of the anomaly towards the west are as follows

TABLE I

For	X	0 ft.	V	350	gamma
	X	400 ,,	V	300	,,
	X	500 ,,	V	200	,,
	X	700 ,,	V	100	,,
	X	1,050 ,,	V	0	,,
	X	1,400 ,,	V	50	,,
	X	1,600 ,,	V	100	,,

(See Fig 3, curve RV)

Assuming cylindrical dimensions, (R 500 ft) infinite vertical depth (Z_2 infinite), depth below surface (Z_1 100 ft.) the following values are calculated :

TABLE II

Z_1/R 0.2

W_1	X/Z_1	X	V	
5.05	0	0	500	gamma
4.0	4.1	410	400	,,
3.0	4.8	480	300	,,
2.0	5.3	530	200	,,
1.0	6.1	610	100	,,
0.5	7.5	750	50	,,
0.1	10.3	1,030	10	,,
0.03	14.9	1,490	3	,,

These results are plotted in Fig. 3, Curve B. They show a general resemblance to the recorded-value curve RV. The absence of negative values in the calculated column is due to the assumption of infinite depth of the cylinder. Limiting the depth Z_2, to 750 ft., the following values are obtained for the lower surface of the cylinder: -

TABLE III.

Z_2/R 1.5

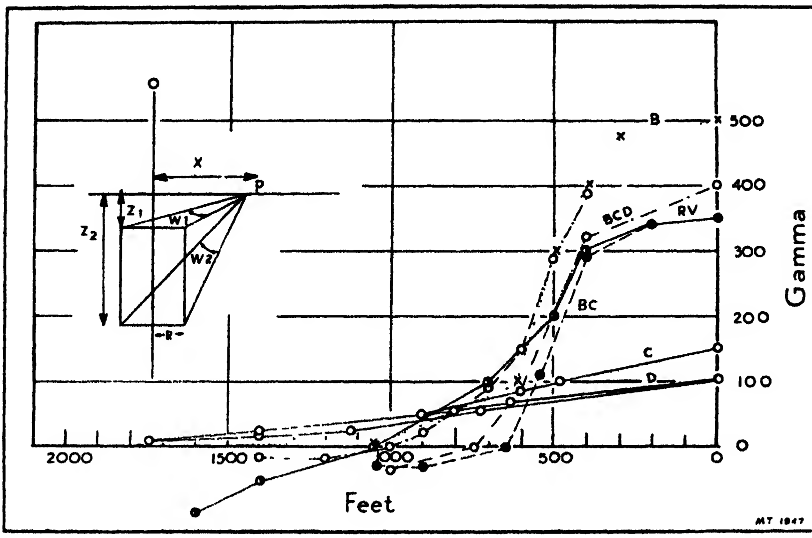
W_2	X/Z_2	X	V	
1.5	0	0	150	gamma
1.0	0.8	480	100	,,
0.5	1.5	900	50	,,
0.03	4.3	2,580	3	,,

These values are represented by curve C, Fig. 3. When subtracted from Curve B, the resultant curve BC is obtained. It is in closer agreement with curve RV than is curve B, and differs appreciably only in the position and extent of negative values. The gradient of the observed values is less steep between X = 500 ft. and X = 1000 ft. This is probably due to the fact that the magnetic body is not of ideal cylindrical form as assumed, but most probably broader in the base and of conical shape with steep slopes. Cylindrical slabs resting on each other and increasing in diameter with depth will approximate the magnetic effect of a magnetic cone. The calculation of this assumed shape was also undertaken. A cylinder at a depth, Z_1, 100 ft. from the surface, and of radius R_1 of 500 ft. was assumed to have a thickness of 200 ft. The lower plane of this cylinder is therefore 300 ft. from the surface (Z_2 300 ft.). This cylinder is assumed to rest on a cylinder with a radius R_2 of 900 ft. and with its lower surface 700 ft. from the surface (Z_3 700 ft.). The magnetic effects of each upper and lower surface of the cylinder were calculated and the resulting values determined and the resulting combination is shown by curve BCD (Fig. 3). A very close agreement exists between the curves BCD and RV, although the calculated negative values are less than the recorded ones. This is probably due to the magnetic influence of magnetic material situated further to the west that could not be taken into account in this calculation. This procedure could be repeated until an even closer agreement between observed and calculated values is reached. To use such refinements at this stage would be inconsistent with the limited knowledge of magnetic susceptibilities and susceptibility contrast.

The geological interpretation of the observed magnetic anomaly at Ohinemutu is governed by the pattern of the anomaly, which can be explained only by postulating a body of material having greater magnetic susceptibility than the surrounding lake beds. Its approximate dimension would be of an order of 1,000 ft. near the surface and 2,000 ft. at its base where it may merge into the main rock mass. Haparangi rhyolites, which are surface features in the vicinity of Ohinemutu, namely at Kawaha Point, Mokoia Island, and Owhata, appear to satisfy the above conditions and their responsibility for the magnetic anomaly appears not unreasonable. Jones suggested in his paper that the flanks of the rhyolite at Ohinemutu are not yet cooled and are thus responsible for part of the thermal activity. On the other hand it may be pointed out that similar masses of rhyolite at Owhata and Owhatea give no indications of being still hot. The present survey favours the assumption

that the rhyolitic protrusion at Ohinemutu is genetically connected with a major fault fracture extending from Whakarewarewa through Ohinemutu to and probably beyond Mokoia Island. By providing passage for ascending magnetic volatiles along its fissures and shrinkage joints it thereby assumes the role of an active focal point of thermal activity.

The same argument applies to the Whakarewarewa anomaly which finds its surface expression in Pohaturoa. Also Pohaturoa is here only an apparent focal point of thermal activity, not its origin.



P	Point of reference
X	Distance from centre of cylinder
Z_1	Depth of upper surface of cylinder from the surface.
Z_2	Depth of lower surface of cylinder from the surface
W_1	Solid angle tended to upper surface of cylinder
W_2	Solid angle tended to lower surface of cylinder
R	Radius of cylinder

Curve RV	Recorded values	
,, B	Calculated values for Z_1	100 ft. Z_2 infinite, R 500 ft
,, C	Calculated values for Z_2 =	750 ft
,, BC	Resultant curve from curves B and C	
,, D	Calculated values for $Z_2 \doteq$ 750 ft	
,, BCD	Resultant curve from curves B, C, and D.	

FIG. 3

From the wider distribution of the magnetic values a more comprehensive picture of the subsurface relief is obtainable. The uniform trends of the magnetic anomaly lines indicate a more regional origin. The iso-anomaly lines strike slightly to the west of north. Local anomalies find prominence only in isolated localities such as Ohinemutu, Owhata, Owhatea and Pohaturoa. The magnetic effects here are due to high relief of magnetic material on the regional magnetic sheet, and genetically they are associated with protrusions of viscous rhyolitic magma. The Owhata and Owhatea anomalies are associated with Pleistocene Haparangi rhyolites, and Pohaturoa with Patetere rhyolites. The association of the Ohinemutu anomaly with a body of Haparangi rhyolite is probable from the discussion above. It is more difficult to

identify the regional magnetic medium. Patetere ignimbrite, which is the lowest member in the sequence of rock formations, may be overlain or intruded by Patetere rhyolites as well as by more recent Haparangi rhyolites. Grange (4) considered that most of the Haparangi rhyolites are younger than the lake-beds. If his evidence is accepted, the choice for the underlying medium narrows to a complex rhyolite-ignimbrite sheet. The magnetic values increase generally to west and east from Rotorua and culminate as a broad feature against the exposed Patetere ignimbrite in both directions. This suggests that the ignimbrite is mainly responsible for the magnetic effect, although locally the strongly magnetized dome-rhyolites are an additional cause. A magnetic cross-section in the area has been considered by the same method of solid angles. The section is assumed to consist of successive vertical cylinders with vertical polarization and extending to infinite depth. The radius of each cylinder was assumed to be 500 ft. and points of reference on the surface were selected at intervals of 1,000 ft. The maximum magnetic value was determined for each cylinder for the reference point $X = 0$, X denoting the distance from the axis of the cylinder. The magnetic values of one cylinder on each side were also calculated and added. As the radius R of each cylinder and its vertical dimensions were kept constant, and Z_2, remained infinite, Z_1, the depth to the upper surface of the cylinder remained the only variable. Z_1, in the ratio Z_1/R, was varied till the product of solid angle and magnetization fell close to the recorded value. The volume per cent. of magnetite was assumed to be 1.3. The susceptibility consequently determined is $3{,}900 . 10^{-6}$, and the intensity of vertical magnetization therefore 0.002. As the solid angles are a function of Z_1/R and X, the total magnetic anomaly is a product of these solid angles and magnetization I. Z_1 can be varied to fit the actual value recorded. Depth to the magnetic medium was determined accordingly but owing to the complex nature of magnetic elements entering into the interpretation the profile obtained should be regarded as indicative only (Fig. 2).

It is interesting to note that most of the thermal activity is observed in the zone of low magnetic values, which cover a strip 1 mile wide and 3 miles long. Hydrothermal actions may have destroyed the magnetism of the underlying rocks resulting in a complete change of magnetic properties.

The average magnetic gradient along the profile section (Fig. 2) is of the order of 130 gamma per 1,000 ft. horizontal distance between the points 3-12, over a range of 9,000 ft. It decreases to 25 gamma per thousand feet between the points 12-14 and is zero between the points 14-17. It rises again gradually towards point 20, steeply 20-21 and gradually towards point 25.

The depression of the profile section to a greater depth than that shown between the points 12 and 19, appears an unlikely solution. It is more probable that the magnetic medium is discontinued at or near these points. With such abrupt discontinuation the anomalies to the west of point 12 arise from a cylinder centered at point 12. The calculated values of 40, 10, and 6 gamma for X 1,200, 2,400, and 3,600 ft., respectively, agree well with recorded values. The same argument applies to explain the magnetic values between the points 21 and 17. The cause of the discontinuity may be structural, or the loss of magnetic properties through hydrothermal actions. The structural discontinuity might be in the nature of a fault or warp.

The zero and negative magnetic values are situated to the south-east, south and west of Ohinemutu. From directly west of Ohinemutu the 0.50, and 100 gamma lines follow for three miles north-south in a narrow pattern. In the north-west portion of the magnetic map, in the vicinity of Utuhina Stream, low values prevail, in consequence presumably of a shallow depression filled by lake beds, bounded further to the west by Ngongotaha and to the south by an extensive ignimbrite sheet. The narrow pattern of the 0, 25, 50, and 100 gamma anomaly-lines, and their general linear meridional trend suggest the existence of a fault-bounded ridge along the valley floor. It represents in all probability a pressure-induced fault scarp along which the earth block to the east subsided. Associated with this movement would be a partial collapse of the floor and the development of fractures parallel to the direction of the main fault. This anomaly pattern extends from Whakarewarewa to Ohinemutu. It probably represents the extension of the sinuous Horohoro Fault, and to the north may connect with the fault along the Kaituna valley.

The alignment of focal points of thermal activity as well as of the young rhyolitic extrusions at Ohinemutu and Mokoia Island, may be cited as additional geological evidence of this meridional trend and as an indication that the fault fracture served as a magmatic feeder-fissure for young Haparangi rhyolite extrusions in the past and for thermal activities at present. It is suggested that magmatic emanations rise along this fracture zone and give origin to the boiling springs at Whakarewarewa, Ohinemutu and elsewhere, and in addition have heated the whole body of ground water saturating the porous beds on which the town of Rotorua is built.

The circular outline of Lake Rotorua may be attributed to the existence of a basin-shaped depression, with roughly circular sub-surface contours. The general north-south trend of the iso-anomaly lines however, would not support this assumption. East of Rotorua they are considered to be the surface expression of an extensive sheet having a northerly strike and general westerly dip. This inclined plane was probably produced by sinking of part of the ignimbrite sheet, and consequently Rotorua is occupying a drowned down-warp. This origin was advanced by Hochstetter, Marshall and Cotton. Marshall revised his opinion and was supported by Park, to advance a theory of origin of Rotorua through volcanic explosion. Grange and his collaborators (4) believed that Rotorua occupies a structural basin in the ignimbrite, due to subsidence following volcanic activity.

RESISTIVITY INVESTIGATION

It was the intention to investigate thoroughly electrical phenomena that were suspected to exist at Rotorua. Only a few preliminary observations were made, but these indicate that useful information may be obtained by electrical methods. The various chemical processes in the thermal area of Rotorua determine to a large extent the electrical properties of the geological bodies. Electro-chemical effects are likely to produce natural earth-currents in chemically polarized bodies, for example the Pleistocene Haparangi ryholites at Ohinemutu. Electric potentials are also created when solutions of different concentrations come into contact with each other or when solutions are forced through a porous medium. The current-conductivity throughout the geological

bodies at Rotorua and elsewhere depends almost entirely on the electric characteristics of the solutions they contain. The lake-beds, consisting of rhyolite, pumice, and sand, are for all practical purposes non-conducting when dry. The electrolyte, however, may vary between the value for pure water, of the order of 30,000 Ohm-cm., and that of concentrated solutions, of 10 to 100 Ohm-cm. Comparison of analyses of waters from different sources with theoretical values show that the resistivity of waters, when less than 1,000 Ohm-cm. can be determined closely enough from their chlorine content alone.

It was the intention to measure resistivities in an area saturated by acidic solutions, in one of alkaline characteristics, and in one of neutral composition. The localities selected for the present studies include Motutara Golf Links (Fig. 4, curve 1), Postmaster Bath, (curve 2 and 3), and the area between the Lake shore and Ngapuni settlement (curve 4). The observed values are calculated to Ohm-ft, (Table IV), and are illustrated in Fig. 4. Resistance values are plotted against electrode separation.

The interpretation of the resistivity curves can be attempted either empirically or on theoretical grounds. Good depth-determinations are possible if the various resistivity values are known. The assumption that depth of penetration equals electrode separation is not always valid, but serves as a guide in the absence of better information. Hummel calculated the effect of simplified two-and three-layer problems and produced approximation curves of apparent resistivities that can be used to advantage. From these it can be deduced whether the shape of a curve indicates a two- or multilayer distribution. The shape of curve 1 is distinctly different from that of the remaining curves. The surface resistivity is of the order of 260 Ohm-ft., and a minimum of 52 Ohm-ft. occurs at an electrode separation of 60 ft. The surface resistivity in the remaining curves 2, 3, and 4 is 50 Ohm-ft which is also the lowest value. Comparing it with theoretical curves, it is apparent that curve 1 represents a multi-layer problem whereas a two-layer problem is illustrated by the remaining curves. Common to all is a minimum resistivity of approximately 50 Ohm-ft. This value appears in curve 1 as a minimum at an electrode separation of 60 ft., and in the remaining curves as surface resistivity. This is not surprising as acidic waters are at or immediately below the surface in the localities where curves 2, 3, and 4 were observed. Curve 1 indicates that the low resistivity medium at Motutara Golf Links is overlain by a medium of a total resistance of 260 Ohm-ft. The geological section at Motutara Golf Links is known only to a depth of approximately 10 ft. It consists of one foot of soil, pumice indurated by silica solutions, and sinter beds. The ground water is at lake level, between 8 and 10 ft. Probably sands and silts from the sequence below this. This complex medium overlying the relatively good conducting medium is represented by the apparent surface resistivity value of 260 Ohm-ft. The medium underlying the low resistivity layer is uniformly high, at least to the depth penetrated on profile curve 1.

Curves 2 and 3 are almost identical. They were observed in the same locality and at right angles to each other. The resistivity gradient rises gradually between 0 and 100 ft. of electrode separation to a value of 100 Ohm-ft. It remains flat between the 100 and 150 ft. electrode separation. This is due to a conducting horizon, presumably a porous layer, at that depth. Curve 4, observed half a mile away, shows a very

gentle resistivity gradient between 0 and 100 ft. separation, and remains constant between 150 and 200 ft. The resistivity characteristics of the curves 2, 3 and 4 are the same, but the depths at which the conducting medium occurs are somewhat different. The area between Ngapuni settlement and the lake shore is thermally active, and known for its occasional gas eruptions, which form craters up to 50 ft. in diameter. The kaolinization there is probably more intense and, as deducible from curve 4, it extends probably to a greater depth than the area of the Postmaster Bath.

The lateral resistivity distribution was examined along two profile lines. The electrode separation remained constant at 100 ft. Both traverses were observed between the Postmaster Bath and Rotorua Racecourse. The resistivity values on traverse 5 indicate no lateral resistivity contrast of consequence. Conditions are apparently uniform for a 100 ft. electrode separation over the observed distance. Traverse 6, observed at an angle to traverse 5, has the same characteristic.

TABLE IV. RESISTIVITY OBSERVATIONS

A Expanding Traverses

Location		
	Motutara Golf Links	1
	Postmaster Bath	2 and 3
	Ngapuni	4

Electrode separation	Observed resistance R Traverses				Apparent resistivities in Ohm-ft.			
(ft.)	1	2	3	4	1	2	3	4
5	6.5	1.6	1.6	1.3	204	50	50	41
10	2.77	0.8	0.72	0.8	174	50	45	50
20	0.77			0.46	97			57
25		0.365	0.32			57	50	
30	0.42			0.27	80			50
40	0.23				58			
50		0.205	0.195	0.21		64	61	66
60	0.14				53			
75				0.14				66
80	0.118				59			
100		0.16	0.17	0.11		100	106	69
150	0.132	0.12	0.115	0.12	124	113	108	113
200		0.107	0.107	0.09		134	134	113
250	0.12				199			

B. Electrode separation constant at 100 ft.

Location · Postmaster Bath.

Observation Station	Observed resistance R Traverse		Apparent resistivities in Ohm-ft Traverse	
	5	6	5	6
1	0.126	0.132	79	83
2	0.127	0.129	79	81
3	0.129	0.128	81	80
4	0.119	0.111	74	69
5	0.135	0.129	84	81
6	0.14	0.111	88	69
7	0.145	0.13	91	82
8	0.14		88	
9	0.143		89	
10	0.123		77	

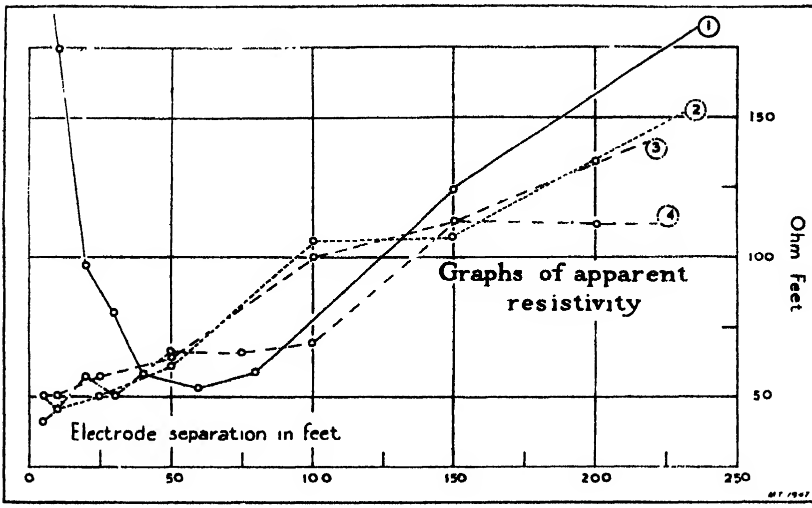


FIG. 4.

Additional observations at varying electrode intervals would permit the drawing of a resistivity map, which may disclose valuable information concerning the lateral and vertical distribution of geologically important thermal factors.

SPONTANEOUS POLARIZATION TESTS

This work was experimental in character and was undertaken in the area situated between the Postmaster Bath and Lake Rotorua. The successful application of this method is dependent on active electro-chemical phenomena. Strong gas discharges of sulphuretted hydrogen are typical in the area of interest. The hydrogen sulphide in this acid or sulphide type of ground is most probably of magnetic origin. Its oxidation both to sulphur and sulphuric acid are well known, and the acidity of the thermal water is accordingly explained. Under the circumstances the most active oxidation will take place at and above the level of groundwater, and the resultant electro-chemical conditions will produce zones of polarity. These zones are characterized by negative polarization ; to determine its maximum and location is the main object. Although the application of this method is simple, attention to details is necessary, especially in the construction of non-polarizable electrodes. To apply a check on their performance it is advisable to interchange the rear and front electrode at each point of observation. Differences between the electrodes amounting to 20 mv. were recorded, although the general discrepancy was more constant and of the order of 10 mv.

No potential profile was drawn from the observed values, as the work was purely of an experimental nature, and insufficient evidence is available for a correct interpretation of the observed values, which varied between 0.6 and 0.7 mv. per foot. Two negative centres which appeared to be associated with slight sulphur mounds were indicated. The course of an equipotential line was also traced. Its general shape was elliptical. Although the information available is scanty, it is sufficiently promising to encourage additional work. All electric

TABLE V. HOT WATER BORES, TOURIST DEPARTMENT

Bore.	Date of Observation 12.12 1941.		15 1 1945.		Temperature (°F)	Heating Value (B T U per lb.).	Remarks
	Flow (Gal. per hour).	Pressure (lb. per sq. in.)	Flow (Gal. per hour).	Pressure (lb per sq in.)			
1	140	Peak of 25	375	7½ constant	211	4.5 Water and Steam	Size of delivery pipe 3 in Constant flow obtained by reducing to 1½ in delivery
2	Came into operation when lifting casing cap for inspection				210		Depth 230 ft.
3	785	30-31 constant	420	30-31 constant	211	4.3	Depth 270 ft. Delivery pipe 2 in.
4	320	7 constant	550	7 constant	211	4.6	3 in delivery pipe reduced to 1½ in Depth 342 ft.
5	290	20	330	20 constant	211	4.7	1½ in pipe. Depth 370 ft.
6				48	211		Depth 340 ft 1½ in. delivery pipe

TABLE VI. COMPOSITION OF BORE WATERS AND KUIRAU LAKE (p.p m.)
Dominion Laboratory Reports K2886/1-2 and L224/1-4

	Bore : 1.	2	3	4.	5	Kuirau Lake
*Na	453	467	483	609	542	339
K	8.7	10.3	17	43	22	34
Rb	.2	.1	.5	.6	.3	.5
Li	4.0	2.0	2.5	3	4	3
Cs	.02	.04	.2	.2	2	.2
NH_4	nil	nil	trace	trace	trace	trace
Al	2.1	2.4	4	1.2	1.4	.5
Ca	2.00	2.36	1	2	2	2
Mg	trace	trace	.4	.9	.5	.3
As	nil	nil	nil	trace	nil	nil
Cl	472	507	489	599	561	348
Br	.6	2.00	1	2	2	2
†HCO_3	409	373	454	653	518	270
SO_4	41.3	40.8	33.3	35.1	33.2	97.2
H_2SiO_3	279	317	268	397	304	443
HBO_2	21.9	19.7	22.1	29.3	28.5	30.6
H_2S	100	62	90	98	105	2
Fe	.87	.87				
Total Solids Summation	—	—	1772	2375	2019	1570
Weighed at 100°c.	1508	1576	-	-		

* Na by difference to balance cations and anions.
† HCO_3 Calculated by difference to balance positive and negative ions

The well waters differ in mineralization, but are all of the same type. The waters are similar in type to a sample from the Rachel Spring, examined in 1912 for the Government Balneologist (6)

The Kuirau Lake water is of similar type but more nearly neutral than the well waters which are well on the alkaline side

investigations have a common economic aspect which was not lost sight of. Corrosion of metal and concrete pipes is often due to natural or induced earth-currents, not confined to thermal regions. The problem is more acute, however, at Rotorua.

HOT WATER SUPPLIES

The hot water supply for the Blue and Ward Bath, situated in the Government Gardens at Rotorua, came originally from a boiling pool situated at the edge of Roto-a-tamaheke at Whakarewarewa. This pool, together with neighbouring pools, receded, owing to a sub-surface drainage re-adjustment, and the water supply ceased suddenly. The writer was present when part of the pools situated in front of the Spout Baths collapsed. The thin crustal sinter shell at the surface remained, while the underlying grey soft mud followed in the wake of the receding water. Air, rising to the surface, formed bizarre shapes of mud-flowers and funnels.

The Rachel Pool in front of the Blue Bath remained the only source of hot water, but could not be relied upon to supply all the hot water required. Alternative hot water sources were considered at Kuirau and Whakarewarewa, where it was intended to use the overflow of the Maggie Papakura Geyser. Urgency, however did not favour either locality, and it was decided to obtain hot water by drilling. Three drilling sites

were selected in the Tourist Department Yard, and two near the former cooling chambers, which were ultimately converted into storage bins for hot water. While Mr. A. Beale, P.W.D. Engineer, energetically directed the various engineering requirements, Mr. J. C. Brown of Rotorua undertook the drilling. Information concerning the various bore-holes, including composition of water is tabulated as far as possible in the Tables V and VI. However, other points of interest worthy of recording arose. When drilling Hole 1, a three inch galvanized pipe was used for casing. The action of the well, when in operation was vigorous, pulsating and continuous. It then settled down to an intermittent period, with spells lasting forty minutes, when it would re-start on its own accord in a vigorous manner. Wells 4 and 5, which were in the same yard, and only approximately 200 ft. from each other, showed similar signs of intermittent discharge. Well 1 had on the 22nd November, 1944, a period of quiescence, lasting from 14.51 hours to 15.31 hours. Well 5, on the same day, stopped from 8.31 hours to 13.25 hours. Both wells repeated this daily whereas Well 4 stopped only every third day. All three wells, at that time, discharged through a $2\frac{1}{2}$ in. pipe. These periods of quiescence were regarded as being due to exhaustion of the heat source, to which all three wells appeared to be related. The reduction of the discharge nozzle to $1\frac{1}{2}$ in. resulted in a continuous flow of hot water. There is, evidently, in this locality, a natural limit of supply which restricts automatically any excessive drain on the thermal resources at the depth from 200-300 ft.

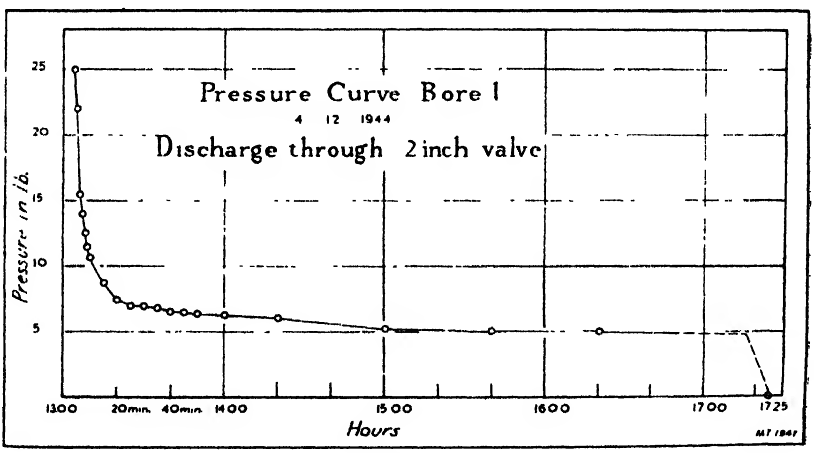


FIG. 5

Pressure readings were taken on Well 1 on the 4th and 5th December, 1944, and the results are shown in Table VII, and illustrated in Fig. 5. The measurements on the 4th were taken just after a period of quiescence. The well reached its peak pressure on the 5th at 08.27 hours. Two months after the installation of Well 1, the ground surrounding it shook violently, and steam issued from cracks in the surface. The well was chilled by forcing cold water through the air sleeve with which it was fitted. It was found that this could be done without apparently affecting neighbouring wells. The period needed for the natural recovery of the well was proportional to the amount of cold water used in chilling.

This is a measure that could be readily used in determining the approximate heat capacity below. It was from these observations that the writer thought it possible to utilize a hot water well as a sink as well as a source. The practical application of this is discussed below. On one occasion the well became nearly uncontrollable when an uninvited hand turned the cooling water off. It re-heated itself and erupted violently. The eruption around the well was caused by corrosion, due to acid waters eating through the casing below the surface. This acidic layer was heated by conduction while the well was operating, thus accentuating corrosion of the pipe, allowing steam and water to escape at this depth. This difficulty was overcome by inserting a 1½ in. pipe and by grouting the space between it and the 3 in. casing. The writer suggested the use of thermal mud bound by sodium silicate as grout. By filling the space between the inner and outer casing with this grout, a heat-and-acid-resisting pipe could be formed. The procedure now adopted consists of using a 4 or 6 in. outer casing, and a 2 in. sleeve. The space between the two pipes is filled by grout.

TABLE VII. PRESSURE OBSERVATIONS BORE 1

Date of observations: From 4/12/44-5/12/44

Observed by E. W. Beale

Time (Hr. and min.).	Pressure (lb.).	Time (Hr. and min.)	Pressure (lb.).
13.04	25	07.57	0
.05	22	08.22	Starting to blow
.06	15½	08.22	17
.07	14	08.27	23½
.08	12½	08.28	18
.09	11½	08.29	14¼
.10	10¾	08.30	12½
.15	8¾	10.15	6
.20	7½	10.40	6
.25	7	11.20	5½
.30	7	12.40	Off
.35	6¾	13.04	Starting to blow
.40	6½	13.07	17
.45	6½	13.08	25
.50	6½	13.10	19½
.55	6½		Observations continue as in previous readings
14.00	6¼		
.10	6¼		
.20	6¼		
15.00	5¾		
.40	5¼		
16.20	5		
17.25	0		

Rachel Pool was kept under constant observation while the drilling proceeded, and during later stages. Variation in its level could not be correlated with the amount of hot water used from the bores. Mr. Beale believes that a direct relation between Lake Rotorua water level and Rachel Pool level has been established. As it was intended to use Kuirau hot lake for the supply of hot water for the Blue and Ward Baths at a later date, the lake was kept under observation over a period extending from the 28th November, 1944 until 23rd July, 1945. The Lake fell 3 in. during that period while rainfall amounted to 35 in. The mean temperature was 168°F., the minimum recorded temperature being 159°F., and the maximum 176°F. The Lake dropped considerably during 1946, reaching a point below the level of its natural outlet

UTILIZATION OF NATURAL HEAT

The most common form of extracting natural heat at Rotorua consists in using thermal water obtained by drilling, either directly in swimming pools or through calorifiers. A simple version of the latter was developed by the Tourist Department. It consists of a sleeve slightly bigger than the hot-water carrying pipe, welded to it at both ends. Town water is then circulated through the sleeve and is heated by convection. Common to both methods is the ultimate discharge of the thermal water into the existing sewerage. This causes some apprehension, as no provision was made for this additional volume of water, nor the possible destruction of pipes by acidic water. This could be successfully overcome by using two wells instead of one, the one to be used as a heat source, and the other as a sink. The hot water of the producing well would be piped along the area required, the pipes being fitted with sleeves where needed, and would discharge into the second hole. The water discharged into this well would still be hot and would require fewer calories for its natural re-heating. The process would be continuous, economic with natural heat resources, and less likely to disturb the natural distribution of hot water.

Rotorua offers the geophysicist a wide field of investigation. Continuous magnetic observations may assist in the future in determining changes in the condition of the underlying magma, gravimetric observations may be used in determining the igneous rock levels, and seismic observations may disclose the alignment of epicentres of local tremors along the main structural zone of instability in this area. Resistivity and spontaneous polarization observations would probably give early indications of changes in the thermal area. Local earthquake tremors may either indicate movement of magma or be associated with downwarping movements which could be regarded as expression of a continuous adjustment along the fundamental fracture.

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TOXICITY OF SOME METALLIC SULPHATES TO THE COMMON HOUSE BORER *ANOBIUM PUNCTATUM* DE GEER

By D. SPILLER, Plant Diseases Division, Department of Scientific and Industrial Research

(*Received for publication, 30th September, 1947*)

Summary

(1) A method has been evolved for testing toxicity of timber preservatives to the common house borer, (*Anobium punctatum* De Geer), by using large numbers of eggs on small treated blocks of susceptible wood. Blocks are examined after nine months for presence or absence of larvae

(2) Using this technique it has been shown that the sulphates of sodium, aluminium, iron, magnesium and manganese are not sufficiently toxic to warrant their consideration as potential wood preservatives

INTRODUCTION

DAMAGE caused to timber through attack by the common house borer *Anobium punctatum* De Geer is widespread and is liable to increase as more sapwood is used in buildings. Various aspects of timber preservation are being investigated by this Division, but pre-treatment to prevent attack by insects is recognized as the most urgent.

While some of the various systems of pressure treatment give satisfactory penetration and distribution of preservative (Harrow unpublished data), it is also necessary to know the amount of preservative which must be used, if attack is to be prevented. These values can only be found by testing the preservative against the insects concerned. Before this could be done it was necessary to evolve a testing technique. Several methods have been tried and then rejected as inadequate. A satisfactory method has now been evolved and is being used to determine the toxicity of various preservatives and potential preservatives.

EXPERIMENTAL METHODS*

Small blocks of wood (approximately inch cubes) are impregnated with preservative under conditions which ensure complete penetration and uniform distribution of the material to be tested. From the weight of treating solution absorbed and its concentration the amount of preservative in the block is calculated. This amount is expressed as a percentage of the calculated oven-dry weight of the block and is then termed "loading." The impregnated blocks are allowed to become air-dry and are then transferred to the testing room for storage. When testing commences the blocks are placed in individual cages and sufficient *Anobium* beetles are introduced to ensure the oviposition of more than 150 eggs on each block. These infested blocks are stored for about nine months at 22.5°C. and 85 per cent. relative humidity, conditions which are known to be very suitable for development of *Anobium* larvae. At the end of this period each block is sectioned on a microtome and the presence (+) or absence (o) of larvae is recorded.

* A detailed description of technique and the various methods evolved for this test will be given in a subsequent paper.

When a series of loadings is employed, the level of complete kill falls between two loadings. Above these values the material is completely toxic, below these values there is insufficient toxicant to give a complete kill. The size of this interval can be reduced by repeating the experiment using more closely spaced loading intervals.

If larvae survive in timber loaded with 2.0 per cent. of preservative, this material can be considered as non-toxic. A reasonably toxic material will give control at or below the 1.0 per cent. level, while highly toxic materials will give complete control at or below a loading of 0.25 per cent. The loading of 0.02 per cent. included in these experiments is beyond the control level of any material as yet tested and is in effect a check on susceptibility of wood, and the adequacy of testing conditions.

In these experiments the test timber was sap kahikatea (*Podocarpus dacrydioides* A. Rich). It is usual to use blocks taken from more than one board, as little is known of the variation in susceptibility to attack of randomly selected boards. Two blocks from each board were tested at each loading.

MATERIALS TESTED AND RESULTS

The number of materials at present available for pre-treatment is not large, and some have characteristics such as being poisonous to man which preclude their widespread employment in the timber-preservation industry. Studies on the cost of preservatives have shown that heavy loading of low-priced materials may be cheaper than smaller loadings of more expensive materials. For this reason it is the intention to test various low priced materials to see whether any of these have a sufficient toxicity to be considered as potential preservatives.

Preliminary tests on the toxicity of five metallic sulphates have now been completed and these results are given in Table I.

TABLE I. TOXICITY OF FIVE METALLIC SULPHATES TO LARVAL *Anobium punctatum* (TEST TIMBER SAP WOOD KAHIKATEA (*Podocarpus dacrydioides*) TWO RANDOM BOARDS A AND D)

Materials Tested *	Loading (Per cent W/W on Oven Dry Wood)					
	2.0		0.25		0.02	
	A	D	A	D	A	D
Sodium sulphate	o +	+ +	+ +	+ +	+ +	+ +
Aluminium sulphate	oo	oo	+ +	+ +	+ +	+ +
Ferrous sulphate	oo	oo	+ +	+ +	+ +	+ +
Magnesium sulphate	o +	+ +	+ +	+ +	o +	+ +
Manganese sulphate	oo	oo	+ +	+ +	+ +	+ +

o No live larvae present in block + Live larvae present in block.

* All materials were commercial grade and loadings include the normal water of crystallization of these salts.

DISCUSSION

Results in Table I show that none of the materials tested was toxic at the 0.25 per cent. loading. Sodium and magnesium sulphates permitted development of larvae even when the loading was 2.0 per cent. and these materials must therefore be regarded as non-toxic to *Anobium* larvae. As there are other materials as cheap as, and more toxic than those tested, it would appear that none of these materials may be regarded as a potential timber preservative.

TOXICITY OF BORIC ACID TO THE COMMON HOUSE BORER *ANOBIUM PUNCTATUM* DE GEER

By D. SPILLER, Plant Diseases Division, Department of Scientific and Industrial Research

(*Received for publication, 6th October, 1947*)

Summary

Tests have shown that boric acid in quantities equal to 0.043 per cent of the dry weight of the treated wood, prevents development of the larvae of *Anobium punctatum* De Geer At 0.022 per cent and below larvae are able to survive

No reference has been found in literature to the toxicity of boron compounds to larvae of the common house borer, *Anobium punctatum* De Geer, but Cummins and Wilson (1936) demonstrated that borax was effective in protecting susceptible hardwoods against *Lyctus* attack. Cummins (1939) showed that boric acid was also effective, and that the quantities of borax, boric acid or a mixture of the two required to prevent attack, contained approximately equal weights of boron. The toxicity of boron compounds to *Lyctus* was remarkable in that as little as 0.11 per cent. of boric acid or 0.13 per cent. of borax prevented infestation.

As boron compounds are cheap and have no public health hazard, it was obvious that their toxicity to *Anobium* larvae should be determined. Tests of boric acid have now been completed. The methods employed were identical with those described in a previous paper (Spiller 1948). In all 131 treated blocks were tested and these covered loadings of boric acid ranging from 0.004 to 3.25 per cent. The test timbers were sap wood kahikatea (*Podocarpus dacrydioides* A. Rich) and sap wood pine (*Pinus radiata* D. Don). Six boards (1, 2, A, B, C, D) of the former and two boards (E, H) of the latter were used. Results are shown in Table I.

DISCUSSION

These results show that boric acid is very toxic to *Anobium* larvae. All loadings of 0.043 per cent. and higher gave a complete kill, while loadings of 0.022 per cent. or less were insufficient to prevent development of larvae. These figures indicate that *Anobium* larvae are even more susceptible to boric acid than are *Lyctus* larvae, which Cummins (1939) showed to be capable of destroying blocks loaded with 0.06 per cent. of boric acid.

Boric acid is cheap, has no public health hazard and does not cause corrosion of treating plants. Hence, its use for commercial pre-treatment of building timbers has no disadvantages.

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TABLE I. TOXICITY OF BORIC ACID TO LARVAE OF *Anobium punctatum*

Year Tested.	Wood Species	Board		Loadings (per cent. W/W Oven Dry Weight of Block). Results (o Blocks With Live Larvae Absent) (+ Blocks With Live Larvae Present).							A.†	B *
1945-46	Kahikatea (*Podocarpus dacrydioides*)	1	Loading per cent.	3.0	2.4	1.5	1.17	0.75			0.75	
			Result	0000	0000	0000	0000	0000 0000				
		2	Loading per cent.	3.25	2.27	1.80	0.97	0.60			0.60	
			Result	0000	0000 0000	0000	0000	0000				
1946-47		A	Loading per cent	1.01	0.50	0.25	0.10	0.059	0.021	0.005	0.059	0.021
			Result	oo	oo	oo	oo	oo	+ +	+ +		
		B	Loading per cent	1.07	0.53	0.27	0.10	0.057	0.020	0.005	0.057	0.020
			Result	oo	oo	oo	oo	oo	+ +	+ +		
		C	Loading per cent	0.74	0.41	0.19	0.07	0.046	0.015	0.004	0.046	0.015
			Result	oo	oo	oo	oo	oo	+ +	+ +		
		D	Loading per cent	0.98	0.54	0.27	0.11	0.065	0.021	0.005	0.065	0.021
			Result	oo	oo	oo	oo	oo	o+	+ +		
	Pine (*Pinus radiata*)	E	Loading per cent	0.97	0.50	0.24	0.08	0.053	0.022	0.005	0.053	0.022
			Result	oo	oo	oo	oo	oo	+ +	+ +		
		H	Loading per cent	0.66	0.35	0.17	0.07	0.043	0.015	0.004	0.043	0.015
			Result	oo	oo	oo	oo	oo	+ +	+ +		
			Higher and Lower Limits of Toxic Range								0.043	0.022

† The lowest loading at which no live larvae were present in test blocks

* The highest loading at which live larvae were present in test blocks

EFFECT OF HEAT TREATMENT ON EQUILIBRIUM MOISTURE CONTENT OF THREE NEW ZEALAND GROWN WOODS

By D. SPILLER, Plant Diseases Division, Department of Scientific and Industrial Research

(*Received for publication, 19th August, 1947*)

Summary

Samples of the three New Zealand woods rimu (*Dacrydium cupressinum* Sol.) kahikatea (*Podocarpus dacrydioides* A. Rich.) and pine (*Pinus radiata* D. Don.) were heated at 86°c., 105°c., 115°c., 130°c., 150°c., for twenty-four hours. Reduction in hygroscopicity was measured by comparing the equilibrium moisture content of the heat treated blocks with that of unheated blocks. With each timber, there was a reduction of from 1.8 to 3.1 per cent. in the E.M.C. at the four lower temperatures. At 150°c. a further reduction of from 1.1 to 1.4 per cent. occurred. The differences between woods and the "woodheat interaction" were significant but of no practical importance.

INTRODUCTION

WHEN wood is heated in an unsaturated atmosphere for appreciable time, hygroscopicity is reduced and the equilibrium moisture content is less than that of unheated samples. The magnitude of this effect depends upon both temperature and duration of treatment. Subsequently, when treated wood is exposed to changes in the humidity of the ambient air, such decreased hygroscopicity reduces shrinkage and swelling of the timber and thus increases its dimensional stability.

Stamm (1937) has shown that this effect of heat on hygroscopicity of wood is permanent and recently Stamm, Burr and Kline (1946) have investigated the magnitude of this reduction at temperatures up to 320°c. with widely varied treating times. They have shown that below 160°c. losses in toughness, hardness and elasticity are less than 10 per cent. and are not likely to prevent commercial adoption of heat treatments for increasing dimensional stability.

Dimensional stability of timber is of considerable importance and, as no information was available on the effect of drastic heat treatments on the hygroscopicity of New Zealand woods, an investigation was undertaken. This paper presents results of initial experiments with three New Zealand timbers, at temperatures up to 150°c.

METHODS

Single straight grained, sapwood boards of rimu *Dacrydium cupressinum* Sol.) kahikatea (*Podocarpus dacrydioides* A. Rich) and pine (*Pinus radiata* D. Don) were each sawn into sixty blocks with dimensions and weights as follows: rimu 11×2.5×4 cm. (97-117 g.); kahikatea 11×5.5×3.7 cm. (87-100 g.); pine 11×6.8×2 cm. (62-70 g.). These blocks were stored in closed tins for a week to equalize moisture. They were then randomized into six groups of thirty blocks, these groups comprising ten blocks of each wood. The blocks were numbered and individually weighed. One of the size groups was then placed for 24

* Blocks of similar size and weight are known to reach equilibrium within a month in this room.

hours in a ventilated drying oven at the required temperature. Five treating temperatures, 86°, 105°, 115°, 130°, and 150°c. were used and the sixth group was retained as an air dry check. After treatment the blocks were cooled in desiccators and each block weighed. After weighing, blocks were open-stacked in a constant temperature and humidity room (22.5°c. and 86 per cent. R.H.) for six months* and then reweighed. From the dry weights recorded after treatment, equilibrium moisture content at 86 per cent. R.H. was computed for each block For unheated blocks, which served as checks, dry weights were computed from the average initial moisture content at 105°c. for each timber.

RESULTS

At the higher temperatures a darkening of wood was apparent, but this was slight. Blocks did not check or crack during treatment or when exposed in the humidity room.

Table I gives the average moisture content of treated blocks after exposure to 86 per cent. R.H. at 22.5°c. while Table II gives an analysis of variance of the complete data from 180 blocks.

TABLE I MEAN PERCENTAGE EQUILIBRIUM MOISTURE CONTENT OF TEN BLOCKS OF TREATED WOOD IN EQUILIBRIUM WITH AIR AT 86 PER CENT R.H. AND 22.5 C

Treatment (Temp c)	Wood Species: Kahikatea	Rimu	Pine
Air dry	19.8	20.1	21.1
86	17.3	17.7	18.1
105	17.5	18.0	18.0
115	17.7	18.3	18.3
130	17.5	17.9	18.0
150	16.4	16.5	16.8

Difference required for significance between any two means 0.4 P 0.01

TABLE II ANALYSIS OF VARIANCE OF COMPLETE DATA (180 BLOCKS)

Source of Variation	Degrees of Freedom.	Sum of Squares	Mean Square.
Heat Treatments	5	227.7	45.5
Woods	2	15.1	7.5
Interaction	10	4.7	0.47
Error	162	17.4	0.107
TOTAL	179	246.9	

Table III lists the changes in hygroscopicity for each wood-temperature combination, as given by the differences between E.M.C. of treatment and check expressed as a percentage of the E.M.C. of the check.

TABLE III. AVERAGE PERCENTAGE LOSS IN HYGROSCOPICITY OF HEAT TREATED WOOD (CALCULATED FROM THE AVERAGE VALUES OF BLOCKS AS SHOWN IN TABLE I)

Treatment (Temp. °c.)	Kahikatea	Rimu.	Pine
Air dry			
86	12.3	11.7	14.2
105	11.5	9.6	13.6
115	10.4	8.7	13.0
130	11.7	10.8	14.5
150	17.2	17.8	20.6

DISCUSSION

Table I shows that all heat treatments reduced the E.M.C., the reduction ranging from 1.8 to 4.3 per cent. Table II shows that these changes are real, that there are also significant differences between means for different woods and that the three woods have not reacted in the same manner. These last two effects are small and of no practical importance.

Reduction in hygroscopicity of pine was more than that of kahikatea and rimu (Table III) due to the higher E.M.C. of the air dry wood of this species in this experiment.

Stamm *et al.* (1946) found that heating pine (*Pinus monticola* D. Don) or spruce (*Picea sitchensis* Carr.) at 150°c. for 24 hours reduced hygroscopicity by about 16 per cent. This figure is very similar to the results of the present experiments (Table III), and confirms the minor importance of timber species and "wood-heat interaction." In general it appears, that, irrespective of timber species, there is a rather uniform drop of 2-3 per cent. when wood is heated at any temperature between 86°c. and 130°c. for twenty-four hours. At 150°c. the E.M.C. is again reduced by approximately one per cent.

Whether such drastic heat treatment is of practical importance depends upon the extent to which the increased dimensional stability is offset by the small losses in hardness, toughness and breaking strength.

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CORRELATION OF SPORADIC E REGION IONIZATION OVER SHORT DISTANCES AND COMPARISON WITH MAGNETIC DISTURBANCES

By V. B. GERARD, Magnetic Observatory, Department of Scientific and Industrial Research

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Summary

By means of simultaneous observations of E_s ionization at several points separated by distances up to 40 km., some new evidence of the horizontal distribution of E_s ionization has been found. An approximately linear relation between correlation coefficient, based on these simultaneous observations of fE_s at different points, and distance has been found. This applies over short distances less than 50 km. The derivation of a rough empirical formula to calculate permissable frequencies for short distance E_s transmission has been attempted. The formula necessitates a knowledge of fE_s at the transmitting location and is very restricted in its application. Indication of moving sporadic E clouds is given, together with the order of the velocity and diameter of one such cloud.

Observations of the horizontal component (H) of the earth's magnetic field permitted simultaneous comparisons of E_s ionization with magnetic disturbances. There was no evidence to show any changes in H as great as 10^{-4} gauss for any of the observed sporadic E ionization.

INTRODUCTION

THE sporadic E region (E_s) is usually defined as an ionized layer existing at the approximate height of the E region, that is from 90 to 140 km., and giving wireless wave reflections at frequencies above the ordinary E_1 critical frequency (f^oE_1). These echoes are sporadic in nature, occurring at any time, but are usually more intense during daylight hours, although usually more frequent near the local midnight (1). Annual curves show a maximum prevalence of E_s in the local summer. E_s virtual heights do not increase as the critical frequency is approached, but the echoes gradually fade out and the critical frequency, usually called the maximum frequency in this case (denoted by fE_s), depends to some extent on the transmitter power, receiver sensitivity and noise level (2). Because of this, observations of fE_s at the same point with different apparatus are not always identical; however, the variation for widely different types of apparatus is seldom greater than ½ mc. s.

Magneto-ionic splitting of the incident beam into the ordinary and extraordinary rays, so well defined in the case of the F_2 layer, is seldom seen in the case of the E_s layer. For this reason it has been recommended (3) that the measured fE_s value be the maximum frequency for E_s echoes. When a definite split is seen, the ordinary ray is measured. However, in the present investigation such a split was seen only on one or two occasions and the fE_s value given refers in every case to the maximum frequency of the E_s echoes.

The exact nature of E_s has long baffled investigators. Some evidence of its physical nature has been reported (4, 5). However, on reviewing the literature one is impressed with the little that is known regarding its distribution over short horizontal distances. Instantaneous observations of fE_s over distances of 80 and 700 km. (2, 4, 6) have been made, but apart from one paper (7) reporting rather pronounced discontinuities between two stations only thirteen miles apart, no other work appears to have been done over short distances.

Harang (8) has found that at Tromso, Norway, sudden increases in fE_s to about 9 mc./s. were accompanied by changes in the horizontal component (H) of the earth's magnetic field of magnitude 0.003 gauss. Other investigators (1, 9) find no correlation between E_s prevalency and world-wide magnetic activity, but instantaneous comparisons were not attempted. To investigate this aspect of the problem, use was made of the magnetic records from the continuous recording Magnetic Observatory at Amberley (see Fig. 1).

APPARATUS AND METHOD

In Canterbury, there is in operation at Lincoln (see Fig. 1) an automatic ionosphere recorder giving h'f (virtual height V. Frequency) curves every half hour and sweeping over a frequency range of 1 to 13 mc./s. in two minutes. The peak pulse output of the transmitter is about 2 kw., the aerials used being four "cage" type broad band dipoles. There is one aerial for transmitting, together with an identical one for receiving the 1 to 4.4 mc./s. band. Two similar smaller aerials are used for the 4.4 to 13 mc./s. band. This apparatus can be made to record an h'f curve every two minutes if desired, and so can give continuous recording. A camera mounted in front of the cathode ray tube of the Lincoln display unit records the h'f curve on photographic film.

At Christchurch, 15.9 km. north-east of Lincoln, a manually operated ionosphere recorded has been installed, the frequency range being 1 to 15 mc/s. and the peak pulse output of the transmitter being in the

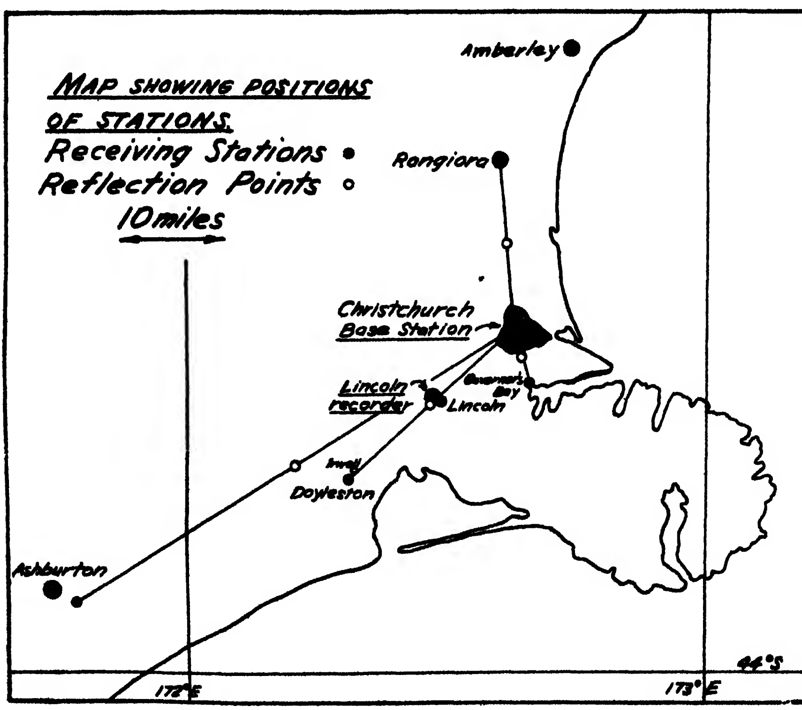

FIG 1

vicinity of 500 w. The aerials used are in this case vertical rhombics, one each for receiving and transmitting for the range 1 to 7.7 mc/s., and likewise one each for the range 7.7 to 15 mc/s.

Thus it will be seen that simultaneous measurements could easily be obtained at these two closely adjacent stations. It was desired to obtain measurements over varying distances somewhat greater than the distance between Christchurch and Lincoln, and for this purpose a portable ionosphere set was built. This will be described below. The object was to set up the portable recorder at suitable points in the district, tune in the Christchurch manually operated transmitter and do a frequency run, plotting an h'f curve simultaneously with the Christchurch operator. The portable recorder will be receiving a slightly oblique signal, but by applying the usual formula for oblique incidence :—

$$fob = f \sec. \phi$$

where f = fE_s in this case

fob = maximum frequency for a wave to be reflected back to ground when incident on the layer at an angle ϕ; the value of fE_s could be simultaneously obtained for three points. The three points would be vertically above Christchurch and Lincoln respectively and at a point midway between Christchurch and the portable recorder. ϕ was of course calculated from the separation between Christchurch and the portable recorder, together with the height of the E_s layer, which for this purpose was taken as 110 km. An examination of the h'f curves obtained revealed no marked variations from a height of 110 km. or E_s and so the use of this value was justified. The sporadic E layer is generally considered to be very thin and so for this layer the virtual height and the actual height must be the same. It has been shown (5) that the above formula is sufficiently accurate for this very thin layer. In any case, over the short distances used, the correction from oblique to vertical incidence was very small, and in some cases negligible.

The portable recorder, which was powered by the A.C. Mains, consisted of a receiver and display unit built into a fairly small cabinet which could be transported from place to place without difficulty. The receiver was a conventional ionosphere receiver covering 1 to 18 mc/s. in three bands with a band width of about 25 kc. The respective stages were, R.F. amplifier, converter, three I.F. stages, infinite impedance detector and a video stage. The video stage could also be used to operate a small P.M. speaker for time signals. The display unit consisted of a 4 in. cathode ray tube with the usual high voltage power supply and a time base which was designed to record equivalent ionosphere heights up to 450 km. The time base was mains synchronized because the Christchurch transmitter is mains pulsed, i.e. the pulse repetition rate is 50 per second. A phase shifting network was used to bring in the echoes received on the correct portion of the time base. An ordinary long wire aerial was used supported by two masts which were bolted together from shorter sections.

The experimental difficulties encountered are listed below :—

(I) As mentioned above, fE_s values measured on different recorders are not always the same. It was decided to take the fE_s value as given by the Christchurch recorder as standard, and correct the values obtained

on both the portable and the Lincoln recorder to this standard. To determine the correction to apply to the portable recorder, this was set up alongside the Christchurch recorder and as many as possible fE_s values obtained, these being measured simultaneously on both sets. The actual correction was negligible over most of the frequency range, because both sets were using the common transmitter and both receivers were very similar in design. It was more difficult to obtain the correction to apply to the Lincoln fE_s values, since it was impracticable to erect the Christchurch apparatus at Lincoln. By choosing a suitable site for the portable recorder it was possible to get oblique reflections from the point vertically above Lincoln and in this way find the correction to apply to Lincoln fE_s values. Doyleston (see Fig. 1) was the site used. Lincoln is of course, midway between Doyleston and Christchurch. At first the portable recorder was installed at Irwell very near Doyleston but bad local noise made reception almost impossible and the gear was shifted to Doyleston. In this way corrections were obtained to correct Lincoln values to those given by the portable set, after correction for oblique incidence, and by means of the Christchurch-portable correction curve, were finally reduced to values which would have been recorded by the Christchurch recorder if this had been installed at Lincoln. The correction in this case was by no means negligible for, as indicated above, the Lincoln and Christchurch recorders were of quite different types. In both cases the correction varied with frequency, as was to be expected, and, to facilitate reducing results, correction curves were drawn. All fE_s values quoted hereafter have had this correction for recorder characteristics applied, and have also been corrected to vertical incidence if necessary.

(II) Since vertical rhombic aerials were used for the Christchurch recorder, whose lobe width was unknown, distances above a certain value would cause a falling off in signal strength, and if very marked, a falling off in the fE_s value recorded by the portable set. Hence it was necessary to restrict the distances used to be sure that this error did not arise.

(III) As no communication existed between the two manual stations, all frequency runs had to be done by a pre-arranged system. Essentially this consisted of covering the frequency range from 2.2 to 5 mc/s., or higher if the fE_s value was above 5 mc/s., in steps of 0.2 mc/s. remaining for 30 seconds on each frequency to plot the h'f curve. As all runs were made in daylight when the E_1 critical frequency was always greater than 2.2 mc/s. it was not necessary to operate below this frequency. The times of all runs were recorded by a watch checked against time signals, while the Lincoln recorder, which was of course operating continuously during hours of recording, is controlled by an electric clock.

(IV) In interpreting the exact value of fE_s from the h'f curve is always a matter of some difficulty since the echo strength usually falls gradually over perhaps ½ mc/s. or more before becoming lost in the background noise. To facilitate interpretation, the echo strength at Christchurch and at the portable site was recorded for each frequency. A very simple index was used :— 1, weak. 2, average. 3, strong. This helped greatly in obtaining fE_s values, but obviously could not be applied to the Lincoln photographic recorder. For this reason Lincoln fE_s values are much more uncertain than those of the manual sets.

TABLE I DETAILS OF LOCATIONS FIXED FOR THE PORTABLE RECORDER

Location of Portable Recorder	Distance from ChCh (km.)	Date of Observations	Time of Observations, N.Z.C.T.	No. of fEs Comparisons with ChCh Recorder.	No. of fEs Comparisons with Lincoln	Remarks
Christchurch.	-	20.5.46 to 25.5.46	Various	24		To obtain correction curve
Governor's Bay	10.4	29.5.46	1325 - 1728	6	0	Lincoln not operating
		30.5.46	0822 - 1219	6	0	" " "
		31.5.46	0958 - 1558	14	20	
		6.6.46	1400 - 1647	4	4	
Rangiora.	25.8	11.6.46	1034 - 1706	23	17	
		12.6.46	1040 - 1606	14	11	
		18.6.46	1018 - 1552	27	28	
Christchurch	--	20.6.46 to 29.6.46	Various			To check correction curve.
Ashburton	80.2	2.7.46	1008 - 1616	21	21	
		4.7.46	1118 - 1618	9	9	
		9.7.46	1120 - 1448	9	13	
Irwell.	29.0	18.7.46	1002 - 1554	Not required	0	Bad local noise } To obtain correction curve.
		23.7.46	1038 - 1116			
Doyleston.	33.4	29.7.46	1320 - 1534	Not required	3	Bad local noise } To obtain correction curve.
		5.8.46	1000 - 1600		12	

(V) For the proper interpretation of the echoes at the portable site it was thought at first that the ground wave would be necessary, but it was found possible to work well outside the range of this wave which was about 25 km. around 2.2 mc/s. Accurate layer heights in these circumstances were not possible but since it was only necessary to distinguish E and F layers, the short ground wave range from the vertical rhombic aerials did not matter.

In all, three other locations beside Doyleston and Irwell were visited, these being Governor's Bay, Rangiora, and Ashburton (see Fig. 1). Table I gives details of the location used for the portable recorder showing their distances from Christchurch which is of course twice the distance between the respective reflection points. In all, 174 comparisons of fE_s between Christchurch and Lincoln were obtained and although a total of 534 manually recorded h'f curves were plotted only about one third of these showed E_s ionization to be present.

RESULTS

(a) *Correlation of fE_s values.*

Correlation coefficients (r) were calculated from the fE_s values obtained at each pair of stations. When E_s ionization was present at one station and not at the other the value of $f°E_1$ was used in the calculation.

Other workers (2, 4, 6) have only calculated the probability that E_s ionization will occur at one station when present at the other, and results are only available over 80 and approximately 700 km. In order to compare the results of the present investigation with these results, probabilities were also calculated, but due to the relatively small number of observations at the different stations, the values differ rather erratically and the correlation coefficient seems to be a much better indication of the relationship.

Table II gives the values obtained for r and the probability over the various distances, together with the results obtained by Eckersley, and by Appleton and Beynon (2, 4). Fig. 2 shows these results in graphical form plotted as r and probability against distance, the arrow showing the mean error for each value of r. The relation between correlation coefficient (r) and distance appears to be linear over the short distances of this investigation, but values over greater distances may not show a linear relation. Due to chance coincidences the probability over greater distances can never be zero as pointed out by Appleton and Beynon (2). However, the value of the correlation coefficient should be zero for distances greater than a certain value, and it would seem that this distance would give the maximum distance over which the ionizing agent causing E_s ionization can act. Hence this distance should be of value in determining the ultimate cause of the sporadic E layer, which is still obscure, apart from Appleton's (4) suggestion that both corpuscular radiation from the sun and meteors may be the ionizing agent. The present investigation does not extend over sufficiently great distances to give even an approximate indication of this distance.

(b) Formula for Short Range E_s Communication.

Let x_1 x_2 . . . . . . x_n be fE_s values for one reflection point, and y_1 y_2 . . . . . . y_n simultaneous values for the other reflection point a distance $\frac{L}{2}$ away. If Δ fE_s is the difference between these pairs of values, then from the values obtained it was found that Δ fE_s is approximately independent of fE_s, and so it may be regarded as a function of distance only. Table III below gives the mean values of Δ fE_s for each pair of stations a distance L apart, i.e. $\frac{L}{2}$ between reflection points.

TABLE III

L km.	2.6	10.4	25.8	29.6	31.8	48.0	51.8	80.2
ΔfE_s mc/s	.205	.223	.269	.182	.591	.501	.469	.659

These values are erratic, due no doubt to the small number of observations and the uncertainty of obtaining an exact value of fE_s from the Lincoln photographic record. The general trend is much the same as would be expected and assuming that Δ fE_s varies linearly with distance we find that :-

$$\Delta\ fE_s = \pm\ 0.011\ L, \text{ where } \Delta\ fE_s \text{ in mc/s.}$$

represents the most probable difference in fE_s between two reflection points a distance $\frac{L}{2}$ km. apart.

Considering the effect of oblique incidence we have :

fob = fE_s sec. ϕ and taking the average height of E_s to be 110 km. then the following formula is obtained :—

$$\text{fob} = (fE_s + 0.011\ L)\ \frac{\sqrt{48{,}400 + L^2}}{220}$$

where fE_s is the value at the transmitter.

Hence, to be reasonably certain of communicating over a range Lkm. using sporadic E reflections, given the value of fE_s in mc/s. at the transmitter, the frequency used should be less than

$$(fE_s - 0.011\ L)\ \frac{\sqrt{48{,}400 + L^2}}{220}\ \text{mc/s.}$$

This may be regarded as a predicted M.U.F. (maximum usable frequency) for the E_s region.

If, on the other hand, communication is not desired within this range L, i.e., that L shall be within the skip distance, then the frequency used should be greater than

$$(fE_s + 0.011\ L)\ \frac{\sqrt{48{,}400 + L^2}}{220}\ \text{mc/s.}$$

This formula could be expected to hold, even if only very roughly, for values of fE_s between 2 and 10 mc/s. and for values of L less than 100 km. It ignores the existence of the ordinary E and F layers. It could only be applied when fE_s is measured on a recorder whose power and sensitivity is of the same order as that of the transmitter and receiver used for the communication. This is because the actual measured fE_s depends to some extent on recorder power and sensitivity.

(*c*) *Moving E_s Clouds.*

Some interesting evidence of the cloud like nature of sporadic E ionisation appeared one day during observations at Ashburton. The observations for the day are shown in graphical form in Fig. 3, similar graphs were drawn for each day's observation but this is the only one to show anything unusal. The observations from 13.50 to 16.20 hours N.Z.C.T. show at 14.20 hours the commencing of the greatest increase in fE_s over the whole period of observations, but unfortunately, due to local interference at Ashburton, the portable recorder could not record between 15.00 and 16.00 hours.

TABLE II. RELATIONSHIPS BETWEEN fE_s OVER VARIOUS DISTANCES

Stations.	Distance Between Reflection Points. (km.)	Correlation Coefficient. (r)	Probability (Per cent.)	Remarks.
Lincoln to Doyleston R P.*	1.3	0.99 ± 0.005**	100	15 Observations
Christchurch to Governor's Bay. R.P.	5.2	0.94 ± 0.02	83	30 Observations
Christchurch to Rangiora R P.	12.9	0.95 ± 0.01	94	64 Observations
Lincoln to Governor's Bay R.P.	14.8	0.95 ± 0.02	63	24 Observations
Christchurch to Lincoln.	15.9	0.92 ± 0.01	84	174 Observations
Lincoln to Ashburton R.P.	24.0	0.91 ± 0.03	86	43 Observations
Lincoln to Rangiora R.P.	25.9	0.85 ± 0.04	96	56 Observations
Christchurch to Ashburton R P.	40.1	0.86 ± 0.04	85	39 Observations
Slough to Great Baddow.	80	Not given	70†	71 Observations (Appleton and Beynon (2))
Slough to Burghead.	700	Not given	26†	Few Observations (Appleton and Beynon (2))
Ottawa to Washington	735	Not given	30††	1800 Observations (Appleton and Beynon (2))
Ottawa to Washington	735	Not given	<10	Estimated by Eckersley (4)

* R.P. = Reflection Point.

** Since the observations at Doyleston were used to obtain the correction to apply to Lincoln fE_s, r is necessarily very close to unity.

† "Intense" E only, i.e. for $fE_s > f^xF_2$.

†† Increases to 70 per cent. in local summer. (Values for all E_s whether "Intense" E or not.)

It will be seen that for every observation without exception the Lincoln fE_s value lies in between the Christchurch and Ashburton values and also the decrease and the subsequent increase and decrease of fE_s occurs first at the Ashburton R.P., then Lincoln, and finally Christchurch. Although too much importance should not be attached to the single isolated set of observations showing this effect, it seems to be real. No other observations show this effect clearly, and it has probably shown up in this case only, because of the large sudden increase in fE_s, and because Ashburton was the farthest location used.

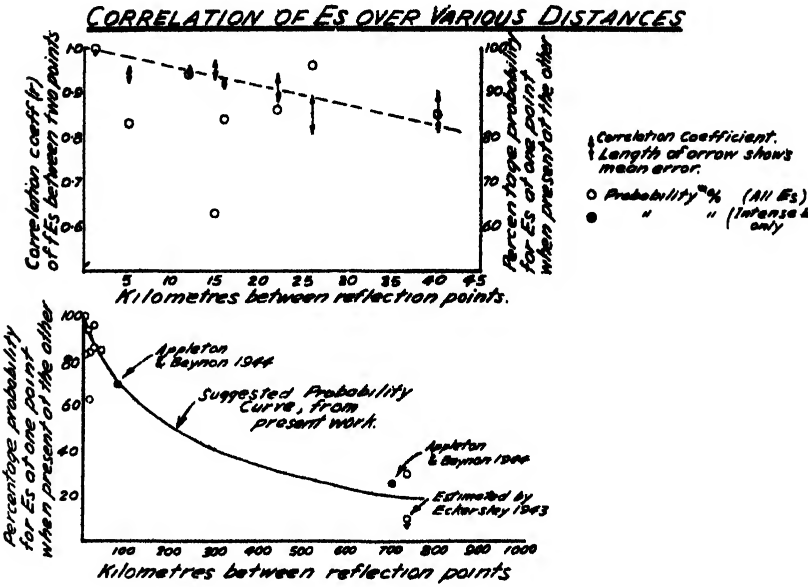

FIG. 2

It would seem then that we must interpret the effect to represent a moving sporadic E ionization cloud whose front reaches Ashburton first. This would mean that the cloud is moving roughly in the direction Ashburton to Christchurch, or, to be more accurate, has one component of its velocity in this direction. Possibly it really represents a movement of the ionizing agent, rather than the actual ions, because of the relatively high recombination coefficient of the E region. The "cloud" appears to have taken about 9 minutes to travel the 40 km. separating the Ashburton reflection point and Christchurch, representing a velocity of 270 km./hour. Although this velocity is high, velocities of the same order have been deduced from meteor trails, which are known to be produced in, or slightly lower than, the E region.

The "cloud" appears to have taken about two hours to pass over each station, giving it a resulting diameter of 540 km. assuming the above velocity. The "cloud" can probably be classed as an "intense" E type since its maximum ionization was greater than that of the F region. Its diameter of 540 km. fits in with the fact noted by other observers (2, 4) that "intense" E ionization is quite often correlated over distances of 700 km.

(d) Comparison with the Earth's Magnetic Field.

A careful comparison of the fE_s changes with those in H has shown that no detectable change occurs, although changes in H greater than 10^{-4} gauss should be found. This indicates that there is no relationship between changes in H and sporadic E ionization.

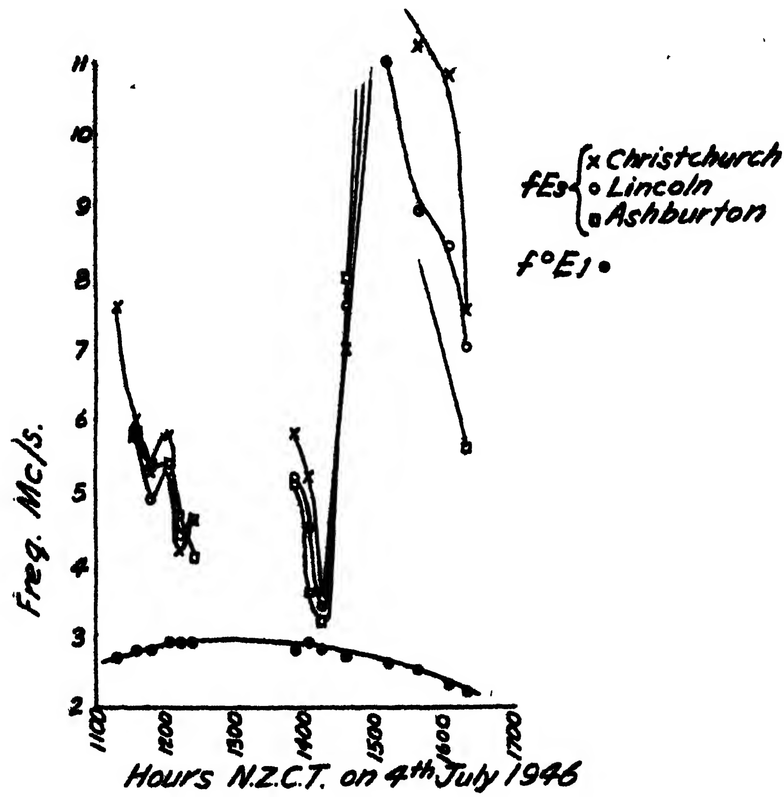

FIG. 3

Although the magnetic recorders are forty odd kilometres north of Christchurch, this should in no way invalidate the above deduction since any changes in H would presumably be due to small corpuscular streams from the sun, and these would produce a magnetic effect over a wide area. The relationship between magnetic storms and auroral activity is well known, as is the fact that E_s frequently is very prevalent during aurorae, but mainly in the auroral zone only. It may be that this type of ionization is caused by different mechanism from that causing the ordinary sporadic E ionization of temperate zones. It would seem that the concurrent disturbance in H and in E_s observed by Harang (8) at Tromso was of the auroral type, since Tromso is well within the auroral zone.

Reported comparisons (1, 9) of E_s activity with the K index of magnetic activity and the 27 day period of solar rotation yield negative results. However, Wells (1) has pointed out that the absence of correlation between E_s and magnetic activity does not necessarily deny the

corpuscular origin of E_s, but may suggest that the local nature and limited extent of the patches of E_s are indications of minute corpuscular streams from the sun which have no effect on the overall magnetic field of the earth. The present investigation would seem to show that although there is no world effect, except in the case of auroral E_s, there is also no local effect exceeding 10^{-4} gauss in H, and this tends to weaken the corpuscular theory considerably. Even small corpuscular streams would be expected to have some magnetic effect, but possibly the effect is very small of the order of less than 10^{-5} gauss, in which case, at even the most magnetically quiet location, it would be completely obscured by larger disturbances.

ACKNOWLEDGMENTS

The writer is indebted to the staff of the Christchurch Ionosphere Laboratory for the valuable help accorded him during the investigation, and he especially wishes to thank Messrs. Gardner, Stanbury and White for helping to operate the Christchurch recorder during the observations. Thanks are also due to Mr. H. R. Atkinson of the Magnetic Observatory for his help in operating the Christchurch recorder as well as for other assistance.

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NEW ZEALAND DIVINERS

By P. A. ONGLEY, Medical School, University of Otago

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Summary

Of seventy-five diviners thoroughly tested, none showed any reliability. An explanation is suggested for the movement of the rod and the apparently spectacular divining successes.

INTRODUCTION

WHILE divining was known to the Persians, Scythians, Medes, and Ancient Germans, modern divining originated in Germany, spread to France, and first appeared in England when Queen Elizabeth introduced diviners to stimulate tin mining in Cornwall.

In New Zealand, divining is widely used. One Southern Education Board employs its regular diviner at all new schools. In a recent Waikato Magistrate's Court decision a well-borer was held negligent for not having taken a diviner with him on first visiting the site of a proposed bore. When the Newmarket Borough Council advertised for a diviner last year thirty applied. The number relying on diviners for cures of various ailments, real and imaginary, is considerable.

While certain investigations have been made overseas, it was felt desirable in view of the widespread activities of diviners in this country, to investigate their ability.

THEORY OF DIVINING

There are two methods of divining, the Method of Samples and the Method of Beats.

In the Method of Samples the diviner holds in his hand a sample of whatever he seeks, in order to insulate him against rays from all other substances. Divinability is claimed to be due to the emission by a substance of rays which may be located by the diviner vertically above the substance.

According to the Method of Beats, each element causes in the rod a definite number of "beats" or movements. These may be positive involving an upward movement of the rod, or negative, involving a downward movement.

The diviner claims that he becomes charged with rays which cause definite beats of his rod. From the number of beats he can identify the particular substance concerned.

An important aspect of divining is what is known as the "theory of reminiscences." It is contended that any substance or person leaves behind a divinable "reminiscence." For instance, if a penny is placed on the floor and then removed it is claimed that the previous presence of the penny may still be detected.

Medical diviners are of two types. Most water diviners believe disease is caused by sleeping over running water. Having found the offending "stream", the diviner treats the patient by placing his bed elsewhere. On the advice of diviners one Central Otago farmer whose house is held to be over a maze of streams now sleeps in his cow byre. (By the Methods of Beats or Samples, however, medical diviners claim to diagnose the actual ailment and the part of the body in which it is located. In both methods they diagnose either from the patient himself or anything, (e.g. handkerchief, garment, sputum, urine, or blood) personal to him.

With the Method of Samples the diviner uses for the standard sample of any particular disease, a piece of wood from a tree suffering from the same disease. Among various botanical samples inspected was an alleged psoriasis which was described by a botanist as a red leaf disease, and a T.B. sample which was identified as a moss-covered twig.

EXPERIMENTAL

The seventy-five diviners tested (including nine women) varied in age from five to eighty-eight years. Occupations included clergymen, teachers, ex-nurses, mechanics, farmers, housewives, mill-hands, labourers, a land-agent, plumber, electrician and grocer. Geographical distribution was: Auckland 1; Taranaki 5; Hawke's Bay 1; Wellington 7; Nelson 1; Canterbury 4; Otago 46; Southland 10. The age distribution of the 118 diviners known to the writer is as follows:—

Age:	0-9;	10-19;	20-29;	30-39;	40-49;	50-59;	60-69;	70-79;	80-89.
No:	1	12	9	14	21	24	27	7	3

While most diviners used forked sticks (Fig. 1)—some dried, some green—two used clock springs, a few used wire, three used pendulums, while many North Islanders used a straight stick held at both ends and bent by the hands (Fig. 2).

In the experiments each diviner has been given a number.

Diviners were tested according to their claims to divine water, minerals, diseases, etc. Rigorous control experiments were carried out to see that:—

(1) There was no interfering substance at the trial site.;

(2) Sufficient material was used;

(3) Containers did not interfere;

(4) Diviners' failures could not be attributed to reminiscences.

STATISTICAL SIGNIFICANCE OF RESULTS

While most results are capable of statistical interpretation the others would appear to be so unreliable as to need no analysis. Three statistical terms need explaining:—

(a) "*Random or Chance Value*" is the number of successes expected by chance. A penny tossed 10 times will probably give five heads and five tails. The chance of scoring 0, 1, 2 . . . . 9, 10 successes in 10 attempts in any number of sets of 10 can be calculated.

(b) "*Necessary for 5 Per Cent. Level of Significance,*" indicates the number of successes necessary if one is to assume the results are not due to chance.

(c) "*Standard Deviation,*" is the square root of the sum of the squares of the deviations from the mean divided by one less than the number of observations.

Unless otherwise stated "4" will mean that the diviner was right four times in ten attempts at saying whether the substance divined for was present or absent. The Random Value will then be 5 and the 5 per cent. level, 9.

In order to give the results more statistical meaning, when a diviner tried say thirty attempts, his results are reported as the number right in each set of ten. Unfortunately, for various obvious reasons it was not possible to subject all diviners to the same number or type of tests.

WATER DIVINING

The fifty-eight water diviners tested were of two types: Type I, who claimed to be able to find water only when it is running underground and Type II, who claimed to be able to find water anywhere.

Experiment A. The diviner was asked to locate an underground stream and define its centre or edges as accurately as he could. He was then asked to locate the same stream when approaching it with his eyes closed, usually from about ten yards away. To find the normal chance deviation, twenty different people tried how closely they could come to a selected mark about ten yards away by approaching with eyes shut. Diviners and non-diviners had the same number of attempts.

In the following table the figures given in the first row indicate the distance in feet at which the subjects stopped when they thought they were at the given mark—the streams in the case of the diviners and the selected marks in the case of the non-diviners.

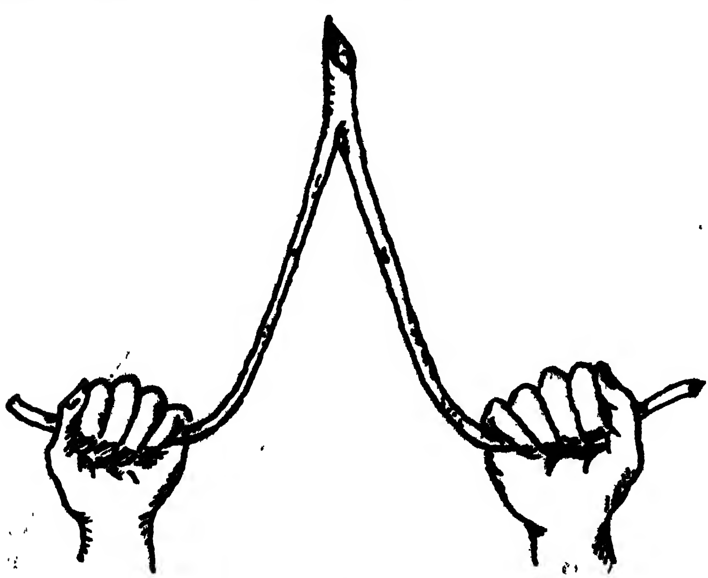

FIG. 1

The figures in the second row show the total number of times diviners erred by these distances, while those in the third row give the corresponding results for the non-diviners.

Row I (Deviation in feet from " stream " or Given Mark.)	>10,	10,	9,	8,	7,	6,	5,	4,	3,	2,	1,	0,	Mean
Row II (No. of times scored by Diviners.)	2	5	6	7	9	9	23	35	56	59	41	38	2.93
Row III (No. of times scored by non-diviners.)	0	0	1	1	2	5	14	20	44	54	72	86	1.74

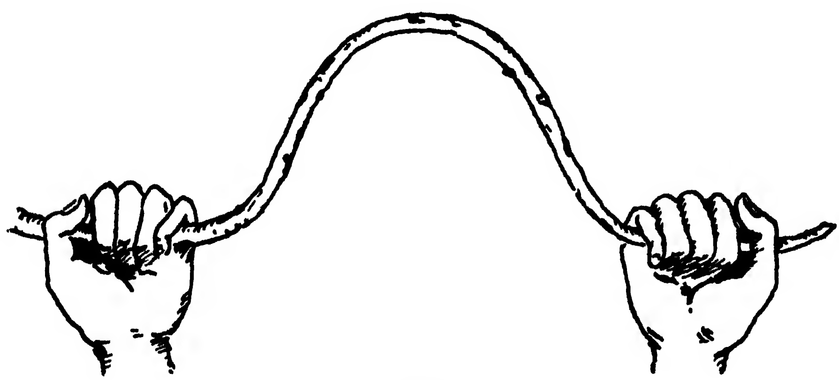

FIG. 2

Experiment B. When the diviner claimed he had found a stream, ten or twenty pegs were put in so that half were above the stream and half were not above it. The diviner also checked each peg " wet " or " dry " as it was put in. These being assumed correct, the object of the test was to see how consistently he could now classify selected pegs on further attempts.

Results :—Diviner No. 29 : 8, 6, 7 ; No. 64 : 3, 6, 6, 5 ; No. 71 : 5, 5 ; No. 72 : 5, 8 ; No. 47 : 9, 8, 7, 6, 9, 2, 4, 3, 1, 5.

Experiment C. Two or more diviners reported on streams crossing a given line, e.g. along a fence, or round the edge of a lawn :—

(i) Diviners No. 6 and No. 10 reported on streams crossing the same two fences. No. 10 found water almost everywhere except where No. 6 found it.

(ii) Diviners Nos. 12, 13, 14 reported on streams crossing a row of trees. If we define the spaces between successive trees as positions 1, 2, etc., No. 13 found water in positions 1, 2, 4, 5, 6, 7 ; No. 14 in positions 3, 8, 9, 15, 18 ; No. 12 nowhere.

(iii) Diviners Nos. 4, 24 and 25 reported on streams crossing the edges of the same lawn. Figures indicate distances from the starting point A, at which the edges of the stream were located. Corners occurred at 27, 64, 147, 202, 220, and 260 ft. from this starting point.

Results :—Diviner No. 4 : 18 to 36, 53 to 70, 121 to 168, 211 to 220. No. 24 : 19 to 27, 33, 64, 79, 98, 124, 141, 157, 177 to 202, 207 to 220, 236 to 240. No. 25 : 21 to 27, 30 to 44, 53 to 64, 82 to 94, 130 to 141, 257 to 260. Results are shown graphically in Fig. 3.

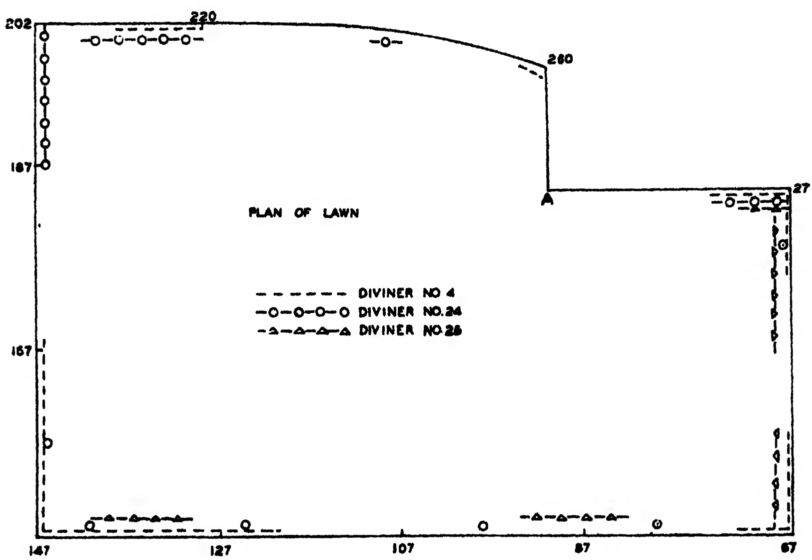

FIG. 3

(iv) Diviner No. 32 claimed to find two streams each about five yards wide and ten to fifteen yards apart. Nos. 33-37 (all belonging to No. 32's family) then tried to find these streams by approaching each edge from off the particular stream. The results tabulated below are explained as follows :—

No. 36 : Since she found the one edge 12 ft. on the dry side of where No. 32 located it, and the second 8 ft. on the wet side she shifted the stream in position and made it 4 ft. wider. All diviners knew their father had found two streams.

Diviner.	STREAM I.			STREAM II.		
	Edge I.	Edge II.	Width W.R.T.* that of No. 32.	Edge I.	Edge II.	Width W.R.T.* that of No. 32.
33	−3	−15	18	−18	−4	22
34	0	9	9	−18	−2	20
35	1	3	−4	Water	in places	from −30 on
36	−12	8	4	2	9	−11
37	No water in either streams or nearby either.					

* With regard to.

Results are shown graphically in Fig. 4.

No. 37, allegedly a good diviner, had done no divining for 5 or 6 years and could not be tested further.

(v) Diviners Nos. 74 and 75 reported on the same three streams.

Stream of No. 74.	1st Attempt of No. 74.	2nd Attempt.	3rd Attempt.
No. 1	5 ft. overshot	Correct	Missed
No. 2	Missed	Tripped over marker	9 ft. overshot
No. 3	15 ft. overshot	Missed	15 ft. overshot*
No. 4	Missed	—	—

* Proceeding from opposite direction to that of first attempt.

Experiment D. Type I diviners were asked by divining a water pipe connected to the street main whether a tap out of sight was on or off.

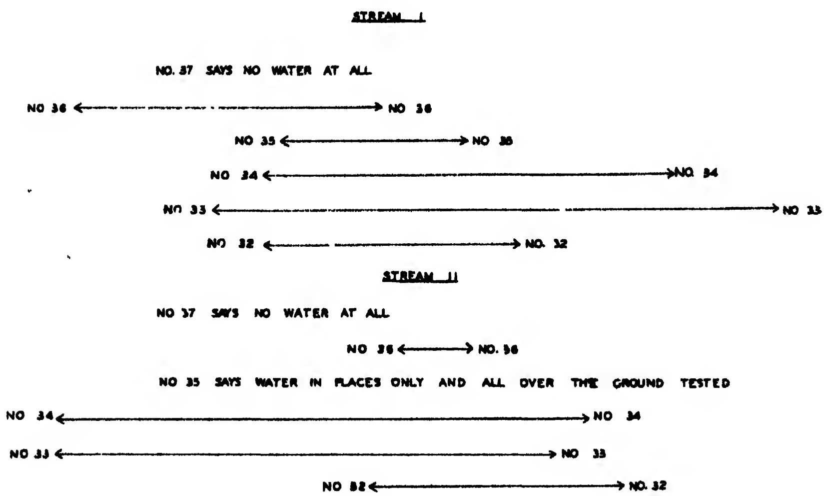

FIG. 4

Results : Diviner No. 6 : 3, 6, 5, 3, 6, 5 ; No. 7 : 7 ; No. 16 : 4, 4 ; No. 19 : 6 ; No. 31 : 4, 5 ; No. 43 : 2, 4 ; No. 44 : 5 ; No. 50 : 7, 4.

Experiment E. Type II were asked to say whether a hidden bottle was full or empty.

Results : Diviner No. 18 : 7, 4, 4 ; No. 23 : 6, 6 ; No. 26 : 3, 6, 6 ; No. 39 : 6 ; No. 42 : 6, 5, 4, 7, 6, 5 ; No. 66 : 4, 7, 5 ; No. 67 : 6, 8, 5 ; No. 17 was asked in which if any of 5 places a bottle of water had been placed. Score : 1 in 5 ; Random Values 1 ; 5 per cent. level, 5.

Experiment F. Some diviners claim the ability to determine the depth of water below the surface. At one spot Diviner No. 6 gave 51, 67, 60, 63, and 130 ft. for the depth ; at another No. 57 gave 5, 9, and 10 ft. at another No. 61 gave 15, 10 and 12 ft.; at another No. 70 gave 18, 21 and 24 ft. Round a well drawing water from 98 ft. (water was also struck

at 32 ft.) No. 10 gave 12, 18 and 46 ft. Over a main 5 ft. below the surface he gave 12, 3, 10, 3 and 11 ft. At a well 20 ft. deep No. 61 gave 6, 6 and 7 ft. Working at a bore slightly downhill from one 31 ft. deep No. 71 said the first was 61 ft. deep. His friends allege it is 71 ft. deep. No. 29 depthed actual wells as follows :—

Actual depths in feet :	56*	20	6-7	1½	4-5	6	5
Depth according to No. 29.	100	100-200	70	50	40	30-40	40

* Water struck at 20 ft. in drilling.

Experiment G. Odd tests.

(i) Diviners Nos. 14 and 46 claimed to have the power to destroy the divinability of a stream by placing an object over it. Tested on the presence or absence of these objects each scored 4.

(ii) Whenever Diviner No. 15 believes he crosses a stream he staggers violently. In a demonstration he consistently staggered at different places. He was not prepared to undertake any tests apart from this demonstration.

(iii) Diviner No. 65 claims to distinguish between clean and polluted water—score 7.

In all the above tests involving 10 questions "yes" or "no" i.e. those included under Methods B, D, E, and G, I tossed an equal number of times with a coin—heads, yes : tails, no.

No. of Successes	0	1	2	3	4	5	6	7	8	9	10	Mean	Standard Deviation
Diviner's Score	0	1	1	5	12	13	15	8	4	2	0	5.3	1.7
Tossing Score	0	1	3	7	10	12	21	7	1	0	0	5.0	1.5
Calculated Expectation	0	1	3	7	13	14	13	7	3	1	0	5.0	1.6

MINERAL DIVINING

Twenty-eight mineral diviners were tested as follows :—

Experiment A. Eleven diviners were asked to pick out iron, tin, zinc and copper from a series of five test tubes. Results are summarized in the following table.

Actual Substances	Number of times identified as metal shown at top of column.			
	Iron	Tin	Zinc	Copper
Iron	*3*	5	5	3
Tin	5	*4*	4	5
Zinc	5	2	*4*	6
Lead	5	2	5	2
Aluminium	3	5	2	2

The above table shows that in seventy-seven attempts at identification there were eleven successful (i.e. those in italics). In this test

the Random Value was 1 in 6. None of the diviners scored anything like correct results or agreed with himself in any second attempt.

Isolated attempts by four other diviners to identify various metals gave similar negative results.

Diviner No. 10 identifies his samples mainly by beats. In the results below when a number but no metal is given for a sample, the sample gave that number of beats which does not correspond with anything known to the diviner.

Actual Substance.	Identified as.
Zinc	—197, 57, Mercury.
Nothing	Lead, Lead, —293.
Mercury	Mercury, Copper, Aluminium.
Lead	Iron, Lead.
Vanadium	Steel.
Tin	Steel, 293.
Magnesium	Steel, —159.

Experiment B. Three diviners reported on mineral samples as follows :—

Actual Mineral.	Diviner's Identification.			
Diviner :	No. 4	No. 8*	No. 8†	No. 9
Iron	Lead	—	Tin	Tin
Gold	*Gold*	—	—	—
Mercury	Tin	—	Zinc	—
Copper	—	Gold	—	Zinc
Zinc	Mercury	Gold	Iron	Magnesium
Iron	Iron and Copper	—	—	—
Tin	—	—	—	Antimony
Antimony	Gold	—	—	—
Silver	Zinc	—	Magne-sium	—
Lead	—	Silver	Silver	—

* 1st attempt. † 2nd attempt.

In the above "—" means that no attempt at identification was made.

The above table indicates that one attempt out of 19 was completely correct and one partially correct.

Random value 1 in 10.

Experiment C. Several who divine only for gold were asked in which if any, of five positions a sample was placed.

Score in five attempts :—Diviner No. 11 : 2 ; No. 12 : 0, 1 ; No. 52 : 1. Random value 1 ; 5 per cent. level 3.

Asked in which of four positions, No. 12 scored 1 in 3 ; told that there might be none, one or two samples in 5 positions, No. 16 scored 2 in 5.

Asked whether a sample was present or not, No. 74 scored 7, 3, 4, 4, and 5 in 10.

Experiment D. Three coal diviners were tested.

Results :—Diviner No. 8 : 5 ; No. 63 : 3 ; No. 70 : 4.

Experiment E. Eight diviners were tested on coins.

Results :—Diviner No. 30 : 7 ; No. 43 : 3 ; No. 47 : 4, 6 ; No. 59 : 5 ; No. 63 : 4, 4, 4, 4 ; No. 67 : 4 ; No. 63 : 4 (for tin); No. 45 : 0 out of 5. No. 46 claimed to distinguish copper, silver and gold, but his efforts in this direction were not successful.

Miscellaneous tests.

(i) In miscellaneous tests Diviner No. 5 scored 0 in 5 ; No. 6, 2 in 6 (twice). Random Value 1 ; 5 per cent. level, 6.

(ii) Diviner No. 39 was sent nine tubes each containing one of the following :—Sodium chloride, Calcium chloride, Zinc sulphate, Magnesium sulphate or water glass-distilled from alkaline permanganate with nothing dissolved in it at all. Reporting on the mineral content, he found forty-one different substances including Sodium cyanide, Phosphine, Magnesium peroxide, Heavy Hydrogen and Heavy Sulphur.

(iii) Diviner No. 65 adopts the H. de France (1) Table of Beats. He twice tested six metals for their beats with the following results. (H. de France values in brackets):—

Aluminium : 6, 3, (not given) ; copper : 6, 3, (6) ; tin : 4, 3, (8) ; iron : 2, 2, (4) ; lead : 4, 5, (13) ; zinc : 4, 5, (5).

HEALTH DIVINING

Eleven health diviners were tested. As far as possible only three patients were used :—

Patient A. Healthy male aged 26, medically examined before and after the tests. Nineteen diagnoses by seven diviners gave him twenty-five different ailments. When diviners did occasionally agree on an odd ailment they usually contradicted one another as to its position in the body, e.g. the five diagnoses of T.B. located the disease in five different places.

Patient B. Healthy male aged 24 was given twelve different ailments by five diviners in nine diagnoses. Most spectacular was the diagnosis of varicose veins in his wooden leg.

Patient C. Female eczema case aged 15. Eight diagnoses by three different diviners gave her nineteen different ailments.

Patient D. Male aged 30 with stomach trouble. One diviner gave him ten other different ailments.

Patient E. Male aged 50 with rheumatics. One diviner gave him ten other different ailments.

Patient F. Female aged 65 with blood pressure. One diviner gave her three other ailments.

Working on sputum samples from patients with chronic and widely different ailments, Diviner No. 2 grouped the papers according to the patients who allegedly supplied them. When told the fifteen samples supplied were three from each of five patients, he grouped them confidently but scored only the random value of successes. With a second set of sputums, Diviner No. 2 selected three out of the fifteen samples as coming from the one patient whose disease he diagnosed as diabetes. The samples selected, however, were from three different patients suffering from (a) duodenal ulcer, (b) pneumonia and (c) heart failure and diabetes.

Experiments with the following three patients show the connection between divination and homeopathy.

Patient G. A female aged 30, wrote to Diviner No. 3 complaining of tiredness and frequent headaches, and enclosing a sample of writing from Patient A. The diviner diagnosed from the writing of Patient A, and sent Patient G, to homeopath-diviner No. 68, who found Patient G had exactly the same peculiar ailments as Patient A. No. 68 studied the heart, head, health and life lines in the patient's hand worked out her astrological chart, studied her eyes, and finally checked the chosen remedy with the divining rod for compatibility with the patient. The diviner suggested that since Patient G's "star had gone into the wrong house," she "would have ill-health for the next twenty years."

Patient H. A male aged 24, has had diabetes for 18 months. On consulting Diviner No. 68 he was told (i) he was under the star of the heart and not the pancreas, (ii) there was, on divination, no trace of diabetes in him, (iii) nevertheless, again on divination, he reacted favourably to insulin and (iv) should break off insulin as soon as possible in favour of homeopathic remedies.

Patient J. A male aged 45, and perfectly healthy went to another homeopath with a story of cancer of the rectum diagnosed medically. When the homeopath asked for a blood sample to send to Diviner No. 2, a sample was provided from a healthy post-mortemed rat. The diagnosis was "serious cancer."

Some diviners claim skill as dietitians. One diviner's patient is claimed to be "ever so much better" since using the divined diet instead of that devised by a public hospital. "He no longer needs insulin." Diviner No. 22 makes this comment on Patient A, "cheese is doubtful, good and bad. You should have a lot more water, onions, egg yolk, gravy wholemeal flour, and treacle. Take a little more milk, coffee, pepper, beer, white flour, mutton, carrot, and no honey, salt, prunes or mutton fat . . . Yours is an unusal test." In one test Diviner No. 21 recommended this patient to sleep over daisies for his cancer.

Diviner No. 10 is in a class by himself. In five tests from handwriting on Patient A, a male, No. 10 declared that four different ailments were involved including "inability to become pregnant." From five sputum samples from Patient C, No. 10 declared there were five different patients with a similar array of ailments. He also claims to tell possible uses for various remedies. Two per cent. acriflavine was supposed to cure thirteen such ailments as heart disease and dropsy ; chloretone was good for such things as syphilis and Parkinson's diseases ; Nyal Bronchitis Cure and ordinary tap water, each effective for about thirty different ailments.

MISCELLANEOUS DIVINING

Tracking. Many Diviners allegedly find people. In attempts to follow where a person had been on a lawn, Diviner No. 10 was decidedly unsuccessful.

Owners. Many diviners claim to identify the owners of objects. In tests, Diviners Nos. 6, 7 and 20 failed. Further evidence against this type of divining is the failure of Nos. 2, 4, 10 and 20 to group according to owners the various samples of handkerchiefs, writing and sputum used in medical tests.

Reminiscences. In tests Diviners No. 6 and 16 failed to recognize reminiscences.

Currants and Gooseberries. Diviner No. 19 can allegedly distinguish between these bushes. Score 2 out of 6 ; Random Value, 3 ; 5 per cent. level, 6.

Sex. Three diviners were tested for ability to determine sex from photographs placed face downwards or from handwriting. Results :— No. 10 : 5 ; No. 54 : 4 ; No. 55 : 3, 6 ; No. 46 : 3 out of 8. Diviner No. 10 when tested with eyes closed described one young lady as a male. He explained his apparent mistake on the ground that she had many male rays in her head. Working from photographs, Diviner No. 55 said a town, an island, and a war memorial were all ladies.

Location of Persons and things. Diviner No. 54 was asked whether certain persons were on a north-south or an east-west line from Dunedin. Score :— 5. No. 58 saying whether a handkerchief was east or west of him also scored 5.

Electricity and Magnetism. Since divinability is often held to be an electrical or magnetic phenomenon, many diviners claim to divine electricity and magnetism. Diviner No. 65 claimed the ability to tell whether a flashlight was on or off—score 4, and to distinguish the poles of a magnet—score 6. No. 74 allegedly gets a reaction under power lines. Working with eyes closed as described in Method A for water he failed badly in five attempts with a telephone, and ten with a high tension wire.

Summary of Tests Involving "Yes" or "No" in Ten Questions. The results of all such tests together with tossing and calculated values are given.

No. of Successes	0	1	2	3	4	5	6	7	8	9	10	Mean	Standard Deviation
Diviner's Score	0	1	2	8	24	18	18	10	4	2	0	5.0	1.6
Tossing	0	1	5	11	14	18	28	9	1	0	0	5.0	1.5
Calculated	0	1	4	10	18	21	18	10	4	1	0	5.0	1.5

Magnetometer Experiments. Franklin and Maby (2) official divining physicists, claim that over divinable water there is a variation of the earth's magnetic field and that there is a deflection in the direction taken up by a compass needle. Diviners Nos. 2 and 3 maintain that a spinning top will destroy any magnetic field and with it the power of any object to be divined. Asked with eyes closed, to say, by their power to divine a nearby object, whether a top was spinning or not, they were wrong as often as right. Magnetometer measurements showed that whether the magnetometer was over ordinary ground, artificial streams of water, still water, or a diviner's water stream or gold seam, the values

of H (the horizontal component of the earth's magnetic field) were always the same. Needless to say spinning tops had no influence on the field of either the earth or a horseshoe magnet. A compass needle over an artificial stream showed no deviation whether water was present or absent, flowing or stationary.

Table of Beats. As mentioned earlier, some identify metals and diseases by the number of beats given.

TABLE I. TABLE OF BEATS

	Zn	Cu	Ag	Pb	Hg	Sn	H	Ca	Ni
1.	5	6	7	13	12	8			
2.	2	-2	3	-3	-3×4	3×5	1	2×2	3×3
3.	-2×2	-2×5	-7	17	-159	-57	3×3	6	4
4.		4×7	2×7						

	Al	Sb	Ag	C	W	Pt	Mg	Au	Fe
1.				6					4
2.	-3×3	5	-5	-11	-13	17	19	7	-23
3.	-37	-47	-79		-43	-17	127		
4.								7	

In Table I, row 1 gives the official (1) number of beats ; row 2 those of the Mosley School of New Zealand diviners ; row 3 those of Diviner No. 10 ; row 4 those of No. 46.

For diseases, Diviner No. 10 and the Mosley School differ likewise (Mosley values given first) :— rheumatism -2 ; -3×3 and -3×4 ; eczema ; -4, -37 ; varicose veins ; -5, -5×3 ; asthma : -7, -3×6 ; catarrh : -11, -3×5.

The Role of Suggestion. From the results given so far, it seems divining reactions are due not to any earthly radiations but to suggestion. Further proof is supplied by Diviner No. 6. As a result of tests he decided paper over an object interfered with its power to be divined, and in control experiments, satisfied himself that his rod would not act if paper was over the object but would do so when the paper was removed. He was timed to see how long the rod took to start or stop moving after the paper was taken away or replaced. One set of experiments was done with eyes open ; the other with eyes closed. While the "eyes open" figures were constant, the "eyes closed" varied considerably. Mean deviations were 1.1 and 3.4 sec. for "eyes open" and 0.75 and 15.9 for "eyes closed."

DISCUSSION

Artificiality of Tests. While it might seem that the best way to test a water diviner is to dig where he divines, this method of testing is so expensive as to be impracticable. To test even one diviner ten or twenty holes, some perhaps hundreds of feet deep would be needed. One must not, as seems to have been done by Macfayden (3) and by the German Reich (4), draw conclusions from too few results. Where independent results of drilling are available (5, 6, 7) they are always against the diviners.

In defence of the methods used, four points may be noted :— (1) Diviners have been invited to suggest possible tests ; (2) in many cases, e.g. identifying metals, the tests used are strict adaptations of those used by the diviners themselves in discovering the extent of their "powers" or in demonstrating their prowess to admiring audiences ; (3) careful control experiments checked that no diviner

was asked to do anything beyond his "powers"; (4) a fair testimonial to the methods used was given by Diviner No. 1 who, asked to explain the consistent diviners' failures, said:—"Your tests are perfectly fair. Until I tried, I would have bet £5 to a penny I would have been successful."

With reference to being blindfolded, or closing the eyes, it has been alleged "since one cannot drive a motor car successfully with eyes closed, neither can one divine." It is noteworthy, however, that the diviners all reported definite results and were sure of them. In no diviner's results was there any constant error indicative of time lag—results were all definitely random. Further, divining is allegedly done by the rod picking up rays—the diviner is there only to hold the rod; if a substance can be divined through hundreds of feet of rock, the added thickness of a bandage or eyelid should hardly interfere.

How the Rod Moves. When the forked stick is held in the usual manner, there are in each limb two types of couple; that type due to the force (H) with which the diviner's hand holds the limb, and that due to the stresses in the rod. The resultant of the latter may be called T. For the rod to move, T must become >H. This may be the result of any or several of four types of usually unconscious and often unnoticeable muscular movements by the diviner's hands.

(1) The diviner may ease his grip slightly, i.e. H decreases.

(2) The diviner may rotate his hands slightly about the wrists. Since palms upwards is an unnatural position in which to hold the hands, rotation is quite likely to occur. As has been shown with an artificial pair of hands linked together (8), such a movement, however slight, gives a pronounced kick of the rod due to additional bending of the rod near the hands. The resulting couple adds to those already existent in the limbs.

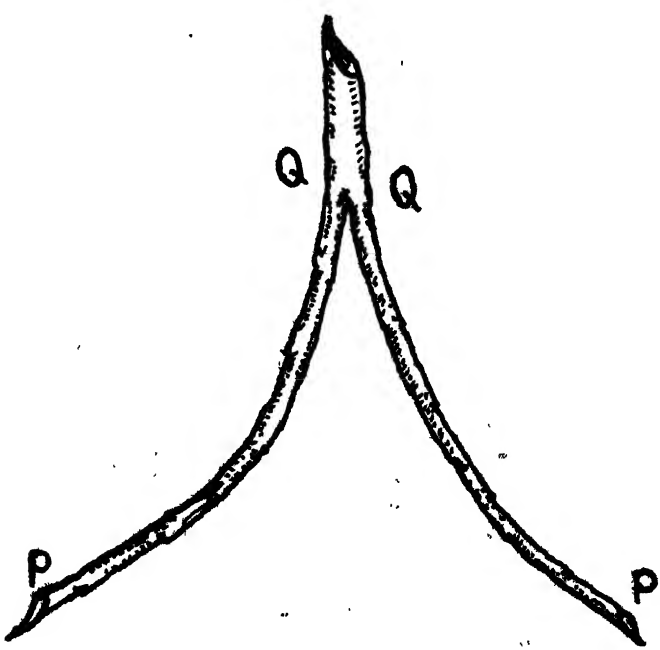

FIG. 5

(3) If the diviner's hands are moved closer together, the curvature of the limbs near P (Fig. 5), and the forces there increase.
(4) If the hands are moved further apart, the curvature of the limbs near Q, and the forces there, increase.

In (3) and (4) there are two compensatory effects. As P increases, Q decreases, and vice versa. The condition for movement is that P+Q increases and becomes >H. This is shown clearly in Fig. 6. If AB and CD represent P and Q, then AMSNC represents the resultant (T) of the forces. Let KL represent H. Then when T > H, i.e. in AM, CN the rod will move.

Whether the rod moves up or down depends on its balance, or original position. An analogy is a bicycle resting on its wheels. When steadied it remains upright ; when it is not steadied, the direction in which it falls depends on its original position.

Much is made by diviners of the fact that the stick will break in their hands. As already pointed out (8) most breaks are not due to a torsion but to a bending movement. Of the several rods I have seen broken, the one torsion break was due to very great uneveness in a straight stick pushed into a loop. That this break occurred when the diviner was adjusting his grip, and before he started divining shows that even torsion breaks may be due to the diviner. As far as breaks are concerned, while a torsion break is no evidence *per se* of the existence of occult forces, a bending break definitely indicates that the diviner moved the rod.

The above discussion of the forked stick is applicable equally to the straight stick, held at both ends, and to the clock spring. The wire held at one end, and the pendulum, move simply because of fatigue and/or involuntary muscular twitches of the diviner. Trying to hold a pendulum still is like trying to ride a bicycle along a line. The more one concentrates, the more one wobbles. It must be remenbered "The best diviners have a nervous disposition."

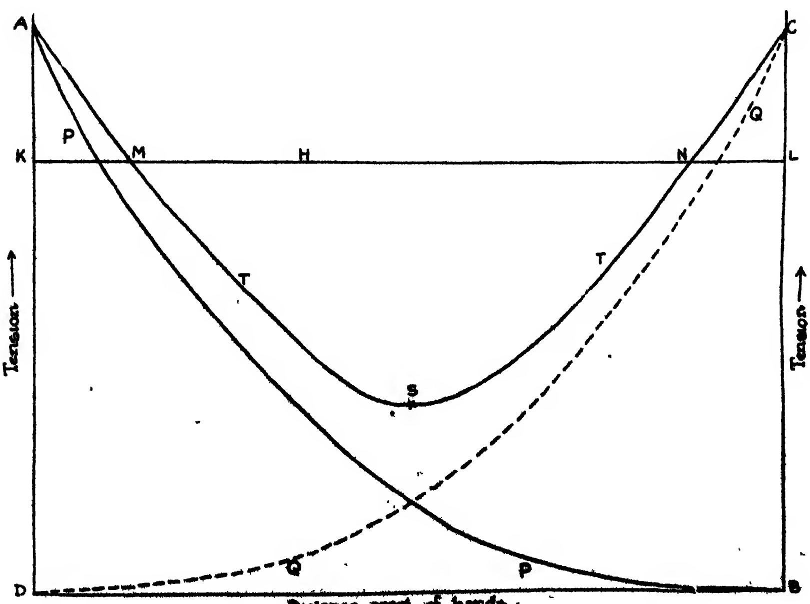

FIG. 6

Since this paper was written, an article has appeared in the *New Zealand Listener* (8) explaining how to manipulate the straight stick held at both ends.

EXPLANATION OF DIVINERS SUCCESSES

Accuracy in diagnosis may be due to good guessing—saying an elderly person has rheumatics, or interpretation of physical signs, e.g. eczema, the homely boil, or the "pop-eye" of goitre or of course a prior knowledge of the patients medical diagnosis.

"Cures" allegedly due to diviners' treatment have also a natural explanation. In the first place the cure may be due to natural causes e.g. a common cold will usually clear up of its own accord. One example of a cure due entirely to natural causes, is the case of No. 20 "curing" his wife of "skin cancer." She is allergic to something in her husband's hay paddock and comes up in lumps on the forearm. He has divined the lumps as skin cancer and found dock leaves to be the antidote. Whenever the wife's lumps appear, she dons her dock-leaf girdle and also keeps out of the hay paddock. The lumps are typical of allergy. Secondly the cure may be due to careful nursing and proper medical treatment. Another patient of Diviner No. 1 was cured of her arthritis not so much by St. John's Wort-sleeping as by the treatment of the village physician. Thirdly the cure may be due to suggestion. A perfectly healthy Australian aborigine who is convinced an enemy has "pointed a bone" at him will die. Conversely, faith in one's medical attendant—physician or diviner—will help greatly towards the cure. Finally there is the curing of a perfectly healthy neurotic woman of the imaginary ailment invented for her by the diviner.

"Successful" water-divining, too, has several natural explanations. In many parts, e.g. the Southland, Waimea, Taieri and Canterbury Plains, it would be hard to miss water. It is significant that while diviners are numerous and objects of veneration in such districts, in hill country, where they would have to possess ability to get many satisfactory results, they are rare and objects of derision. If one could plot the distribution of New Zealand diviners, one would probably find that it followed roughly the probable distribution of sub-surface water as shown by Henderson in his map of the water-bearing strata (10).

The position was fairly summed up by a Dunedin plumber and well-sinker who used to employ a diviner. The latter was right whenever working on the flat and usually wrong all other times. One of his few successes in hill country was when he divined a water supply for a medical man's summer residence. Unfortunately, it was not found until the work was finished that the supply was the wastage from the neighbour's septic tank.

Such success as are met in hill country are due to the use of common sense, e.g. "finding" water where increased vegetation suggests its presence, or in valleys, or the mouths of gullies. One such "success" of a prominent Otago diviner was the prediction of water at the mouth of a gully on ground sloping gently from the hill to the Shag River about ten chains away and fifty feet lower down.

"Geological Common Sense" will enable the diviner to predict not only the presence of water but also its depth below ground. In the Southern Wairarapa, for example, where water level is approximately that of Lake Wairarapa, knowledge of the height of a particular place above the lake level indicates how deep one will have to go to strike water.

One often meets the case of two wells A and B. A is undivined, is a failure and has gone dry; B, divined, and sunk to the same depth, is a spectacular success. (The many cases of the converse are of course discreetly forgotten). Several explanations exist. First, any bore may silt up. Cleaning out the old bore is more efficient if less spectacular than sinking a new bore. Secondly, in drilling it is possible unwittingly to pass right through a water layer. Finally, it must be remembered that the slope of the water table is not necessarily that of the surface. A case at Oturehua in Central Otago 1700 ft. above sea level is interesting. Cross section of the strata is shown in Fig. 7. A bore was sunk at sixty feet at A until a hard shell bearing layer MN was struck. Water was then divined at B, a chain away and two or three feet higher up the hillside. On boring, water was struck at sixty feet at D. In the plane of the bores AEDB, the water table CD slopes more steeply than the surface AB. Had AE been continued through the shell layer MN, water would have been struck at C.

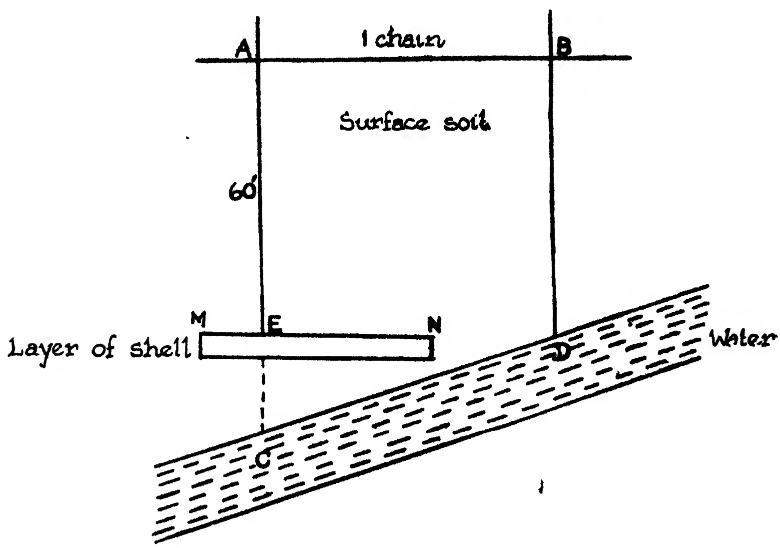

FIG. 7

CONCLUSION

Divining has, throughout its history, been associated with superstition and magic. Minerva with his rod turned the aged Ulysses into a youth and back again to a man. The Roman Augur used his lituus or rod to "divine" the future; Cicero, himself an augur, says he does not know how two augurs meeting in the street could look each other in the face without laughing. The earlier Cornish diviners knew "the rod is guided to the ore by pixies, the fairy custodians of the earth." Modern relics of superstition are the wide-spread use by healing diviners of mistletoe, the favourite plant of the Druids, and the use of urine for diagnosis, c.f. Shakespeare's derision of "piddle-doctors."

Divining has been debunked before. In a pamphlet by Ellis in 1917 (11) it is said:— "It is difficult to see how for practical purposes the entire matter could be more thoroughly discredited and it should

be obvious to everyone that further tests of this so-called 'witching' for oil, water, or other minerals would be a misuse of public funds." However, in view of the widespread belief in divination in this country, and elsewhere, further investigation was necessary.

It has been shown there are probably hundreds of diviners in practice in New Zealand to-day including at least fifteen medical diviners. These latter can do considerable harm. The farmer can be put to considerable expense by the water diviner by (1) payment of his fees ; (2) unnecessary and fruitless drilling ; (3) having to pipe water from awkwardly-placed wells. Companies have been and are being floated on the diviners' prospecting prowess. In the case of a Southland company, when finally, no oil whatever was struck, the diviner apologetically announced he had mistaken coal for oil. One Taranaki oil company is at present depending on a diviner for its prospecting. This man, as accurate as any other diviner tested, claims to have proved that the main oil supply for California flows from Taranaki under Mt. Ruapehu. The bed shifting and manuka-sleeping antics of the medical diviner are exacting a toll of human suffering and death.

Of the seventy-five diviners tested representative of all occupations and from all parts of New Zealand, not one showed the slightest accuracy in any branch of divination. That 90 per cent. of the diviners are sincere does not lessen the harm they do.

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MIDDLE TERTIARY STRATA AT SMITE RIVER, LAKE HERON, NEW ZEALAND

By BRIAN MASON, Canterbury University College

(*Received for publication, 4th August, 1947*)

Summary

A small fault involved outlier in Smite River valley, close to the Main Divide, is described. Macro- and micro-faunal studies indicate that a condensed section of shore-line, terrestrial and marine sediments of lower and middle Tertiary age occurs at this locality, with the Waitakian (Upper Oligocene) missing. The lower Tertiary palaeography is briefly discussed.

IN 1873 Haast recorded the presence of fossiliferous Tertiary rocks in the valley of the Smite River (called Symthe River by Haast), which flows into the stream draining Lake Heron from the mountains to the north-east of the lake itself. As no more recent description than that of Haast is available, and as this occurrence occupies a critical position close to the Main Divide and inland from the classical Mt. Somers district, it was re-examined in February, 1947.

Access to the locality is by the Lake Heron road which terminates on the station at the outlet of the lake. The station buildings are situated on the broad fan of the Smite River where it flows from a narrow gorge-like valley into the broad intermontane basin. Where the river enters the basin its valley is cut in greywacke and argillite, and the Tertiary rocks occur about three miles further upstream, on the northern side of the valley. They cover only a small area, less than a mile square are poorly exposed, and are badly slumped. They are evidently deeply involved in the greywacke and argillite, but their actual relationship to these rocks was not visible.

Haast gives a detailed account of the section, which was probably better exposed at the time. His description is as follows:

"The lowest beds consist of:

(1) Dark greyish sands with small seams or streaks of shaly coal, the planes of divisions sometimes covered with crystals of selenite, thickness variable, from 30 to 60 ft.

(2) They gradually alter to fine loose quartzose sands, generally white, sometimes with pinkish or salmon-coloured hues, about 80 ft.

(3) These are overlaid by dark brownish greensands, changing gradually to dark green tints, containing *Pecten hochstetteri* and *Waldhemia lenticularis*, strike 170°, dip S. to E. 42°, about 40 ft.

(4) They become more arenaceous, and then change into shell sands full of teeth of fishes, identical in character with the Trellissic series of the upper Waimakariri and containing *Turitella* (sic) *gigantea*, *Pectunculus laticostatus*, *Crassatella ponderosa*, *Cucullaea*, about 35 ft.

(5) These are capped by greyish sands, unfossiliferous, about 20 ft. thick, and which have been preserved from destruction by two beds of hard shell limestone, thickness about 4 ft., each divided by 6 ft. of sands containing many of the Pareora fossils. Besides those already named as occurring in No. 4, I observed the large *Fusus spinosus* and several species of *Struthiolaria*."

From the exposures now visible, Haast's description of the sequence and of the nature and thickness of the beds appears essentially correct,

and there is nothing to add to the description. The interest lies in the interpretation in the light of the standard Tertiary succession and the comparison of the sequence with that of adjoining districts.

The lowest beds exposed in 1947 were dark greensands and glauconitic sandstone, evidently corresponding to Haast's No. 3. The greensands contained *Lentipecten hochstetteri* (Zittel) and numerous brachiopods. Dr. R. S. Allan has supplied the following note on the brachiopods collected :

Aetheia gualteri (Morris)	2 specimens
Waiparia (?) *elliptica* (Thomson)	abundant
Rhizothyris sp. — dwarf species	1 specimen

"This combination of species is distinctive of Duntroonian stage to which *Waiparia* (?) *elliptica* (Thomson) is restricted. *Aetheia gualteri* (Morris) has a longer range but is always an adundant species in Duntroonian rocks which contain brachiopoda."

Two samples from these beds were sent to Dr. H. J. Finlay for examination of their foraminifera fauna. He reports a similar fauna from each, containing *Gyriodina allani* Finlay, *Semivulvulina waitakia* Finlay, *Guttulina communis* (d'Orbigny), *Arenodosaria antipoda* (Stache), *Nonion pompiloides* (Fichte and Moll), *Notorotalia spinosa* (Chapman), and *Cassidulina* afl. *crassa* d'Orbigny, indicating a Duntroonian age.

Thus the fossil evidence enables the greensand and glauconitic sandstone to be correlated with Duntroonian strata elsewhere.

The sequence above these beds is obscured by slumping, and higher exposures consist of soft white and yellow quartz sands with hard concretionary bands containing mollusca, largely in a fragmentary condition. Samples from these beds were barren of foraminifera. These beds are evidently Haast's No. 5. The following identifications of the mollusca have been made by Mr. C. A. Fleming, of the New Zealand Geological Survey :

Nucula cf. *nitidula* (A.Ad.)
Angulus (*Paronidea*) *edgari* (Ired.)
Maorimactra cf. *accuminella* Fin.
Maorimactra chrydaea (Suter)
Scalpomactra biconvexa (P. and B.)
Austrovenus h. sp.
Notocallista ?
Myadora sp. indet.
Gari aff. *stangeri* (Gray)
Conominolia ? aff. *sulcatina* (Sut.)
Patelloida sp.
Polinices cf. *modestus* (Marw.)
Parvacmea ? sp.
Taniella socia Fin.
Maoricolpus n.sp.
Struthiolaria subspinosa (Marw.)
Struthiolaria tuberculata (Hutt.)
Sigapatella sp.
Maoricrypta radiata (Hutt.)
Zelandiella cf. *subnodosa* (Sut.)
Zeacuminia n.sp. aff. *pareorensis* (Sut.)
Pupa aff. *alba* (Hutt.)
Cylichnina sp.

Mr. Fleming comments as follows on this fauna: "A most tantalising fauna of shallow water facies making comparison difficult. *Scalpomactra biconvexa* is Altonian and distinct from the Pareora Series *continua*, but that might not be worth much. *Austrovenus* is rare in the Miocene (the genus lives tidally or in water under two fathoms). The species at Smite River is like that from near the Mokau coal horizon taken at present as separating Awamoan from Altonian. There are no older occurrences and the next higher is a different species from Waiauan ? of Buller River.

"The *Maoricolpus* is not an exact match for the Target Gulley form but is no closer to anything else. The two *Struthiolaria* occur in the Awamoan, *subspinosa* going higher, and *tuberculata* being common in some of the "Pareora" Trelissick beds. *Zelandiella* occurs first at White Rock River, at present considered Awamoan, but it is not present in the Otago Awamoan."

From Mr. Fleming's remarks it would appear that the most probable age for the beds containing this molluscan fauna is Awamoan or prehaps Altonian.

The nearest Tertiary sequences with which the Lake Heron occurrence can be compared are those at Redcliff Gully (Speight, 1912) and in the Mt. Somers district (Speight, 1938). By these comparisons, and from the meagre fossil evidence the Lake Heron succession can be interpreted in the following way.

Haast's No. 1 evidently corresponds to the coal measures of the Mt. Somers district, which Speight puts down as Ngaparan, but these beds are very thin in the Lake Heron inlier. Haast's No. 2 probably corresponds to beds of similar lithology in the Mt. Somers district, which there contain Bortonian mollusca.

Nothing corresponding to the Ototaran marl of the Mt. Somers district occurs at Lake Heron, although it may be represented by beds of different lithology viz. sands. The Duntroonian greensands are similar both at Lake Heron and in the Mt. Somers District, and Awamoan beds seem to be present in both places. The most significant difference between the succession at Mt. Somers and Redcliff Gully and that at Lake Heron is the absence in the latter place of the (Waitakian ?) limestone, which is such a prominent member of the sequence in the other districts. At Lake Heron too, the volcanic matter interbedded with and underlying the limestone is absent, although the dark greensands may be tuffaceous. The sequence is also considerably thinner at Lake Heron. All these facts, together with the extreme sandiness of the Lake Heron beds, suggest that this area lay close to the old land mass from which these sediments were derived in middle Tertiary times. Oscillations which caused little change in off-shore sedimentation may have raised the Lake Heron area above sea level and thus caused contemporary erosion. It appears highly probable that land existed along the line of the present Main Divide in this area. The nearest Tertiary rocks on the far side of the Main Divide are those at Ross, about forty miles to the north-west of Lake Heron, where Gage (1945) has recorded greensand, calcareous sandstone, and limestone probably of Whaingaroan or Duntroonian age. These beds at Ross may represent deposits off the western coast of this old landmass, whereas the Lake Heron beds represent deposits on the eastern shore. In this connection it would be most

interesting if beds of similar age were found between these two occu rences. Tertiary rocks have been recorded from the ranges on th western side of the Lake Heron depression, and their detailed examinatio should yield pertinent facts as to the local palaeogeography in middl Tertiary times.

ACKNOWLEDGMENTS

I would like to express my appreciation to my brother, Mr. A. F Mason, for his company and assistance in the field, and to Dr. H. Finlay, Dr. R. S. Allan, and Mr. C. A. Fleming for their palaeonto logical work.

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CHARACTERISTICS OF SIX NEW ZEALAND MADE DAIRY WATER HEATERS

By N. L. MASEYK, Dominion Physical Laboratory, Department of Scientific and Industrial Research, Lower Hutt

(*Received for publication, 7th July, 1947*)

Summary

This report gives the results of measurements made on six different dairy water heaters manufactured in New Zealand. It aims to provide manufacturers with data from which the qualities of their heaters may be deduced, and to give to the Dairy Research Board data concerning the efficiencies of dairy water heaters being supplied to New Zealand farmers

Several bases for comparison are provided in the statements of the efficiencies under different conditions and of the power required to maintain the boiler at an elevated temperature. An estimate of the performance under a specified set of working conditions is given.

Finally an attempt is made to determine how much of the loss at 180°F. occurs through the insulating material, how much through the uninsulated surfaces, or by evaporation.

The information is given mostly in the form of tables.

MEASUREMENTS

THE boiler was placed in a chamber the temperature of which was kept between 40°F. and 45°F. and in which a fan produced a gentle flow of air. Power was fed in at the approximately constant voltage of 230.

The main experiment consisted in measuring the time required and the amount of work, in watt-hours, necessary to raise the temperature of the water through a given range, and in determining the power required to hold the temperature steady at a finally selected value. Thermocouples were used to record temperatures and a commercial watt-hour meter to measure electrical input.

An accuracy in the readings of 1 part in 100 was striven for and to this end temperatures were recorded to the nearest °F., electrical input to .01 kwh. time to .1 hour and capacities to .1 gal.

Additional measurements were made to ascertain the power required to hold the temperature steady when such parts as taps, funnels, recesses for thermostats and heating elements in contact with the inner surface and also exposed to the air, were lagged with Linwool 2 in. thick (see Table I row 11).

Finally, an estimate was made of the amount of water evaporating in 24 hours.

The accuracy of the method in these last measurements was such as to indicate only the order of certain inferences drawn therefrom.

BASIC DATA

Below are listed the few physical relationships which are required for calculations and interpretation of the results.

Density of water. Very nearly 10 lb./gallon.

1 B.T.U. is the amount of heat required to raise 1lb. of water through 1°F.

1 B.T.U. = .293 watt-hours.

To heat 1 gallon of water through 100°F. requires .293 kWh.

To evaporate 1 gallon of water at 180°F. requires the expenditure of about 3 kWh.

TABLE I. EXPERIMENTAL RESULTS

Tests.	Unit of Measurement.	Heater.					
		A.	B.	C.	D.	E.	F.
1. Total Capacity of Heater.	Gallons	30	28.6	28.5	27.7	22.4	20.3
2. Volume above tap.	,,	24.9	27.4	21.2	22.4	17.5	15.9
3. Volume below tap.	,,	5.1	1.2	7.3	5.3	4.9	4.4
4. Mean ambient temperature.	°F.	43	43	43	43	43	43
5. Initial Temperature of Water.	°F.	80	80	80	80	80	80
6. Final Temperature of Water.	°F.	180	180	180	180	180	180
7. Input Power.	Watts	710	750	800	750	780	610
8. Time to Heat.	Hours	18.2	14.6	14.1	14.6	11.0	12.5
9. Energy Expended.	kwh.	12.92	10.95	11.28	10.95	8.58	7.63
10. Power required to maintain temp. at 180°F. with ambient temperature 43°F.	Watts	360	230	350	310	270	280
11. Power required to maintain temp. at 180°F. with extra insulation and ambient temperature 43°F.	Watts	260	210	200	290	170	200
12. Evaporation in 24 hours at 180°F.	Gallons		.1	.6	1.0	Neg.	.4

Neg. = Negligible.

PERFORMANCE CHARACTERISTICS

(a) *Reduction of Data.*

The first basis for comparison is provided in the reduction of the experimental results to refer to the same input power. 750 w., the nominal rating of most of the heating elements supplied, is arbitrarily chosen for this purpose. It is assumed that with the ambient temperature and the limits of the heating range unaltered, the mean value of the power loss is also unaltered, when the input power given in Table I is changed by the small amount necessary to make it 750 w.

Though the efficiency given in Table II row 8 is derived for an arbitrary set of conditions, it yet gives a measure of the combined effects of size and quality of design on performance.

(b) *Heating in Limited Time with Optimum Power.*

For the heating-up period alone the efficiency will improve with increasing power input. However in use the heater will be required to deliver its hot water every so often and then the optimum power is that which just brings the water to the required temperation in the given time. That this is so may be simply demonstrated as follows :—

ABC, ADC, are the time-temperature graphs of any heater. AE represents the time after commencement of heating when the hot water is required.

In one case the water reaches the final temperature in time Ab and is maintained at this temperature for time bE. In the other it just reaches the final temperature in time AE.

TABLE II. REDUCTION OF DATA TO INPUT POWER OF 750 W. AND COMPARISON OF EFFICIENCIES FOR PERIOD OF HEATING-UP ONLY

	Unit of Measurement.	Heater.					
		A.	B.	C.	D.	E.	F.
1. Energy required to heat water from 80°F. to 180°F. without loss.	kWh.	8.79	8.38	8.35	8.11	6.56	5.95
2. Energy supplied while heating (see Table I, Row 9).		12.92	10.95	11.28	10.95	8.58	7.63
3 Energy lost = (2) - (1).	kWh	4.13	2.57	2.93	2.84	2.02	1.68
4 Mean value of power loss.	Watts	227	176	208	195	184	134
5. With input 750 w. mean power available for heating.	Watts	523	574	542	555	566	616
6. Time to heat from 80°F. to 180°F. with input power of 750 w. and ambient temperature 43°F.	Hours	16.8	14.6	15.4	14.6	11.6	9.7
7. Energy expended in heating from 80°F. to 180°F. with power input 750 w.	kWh.	12.6	10.95	11.55	10.95	8.70	7.28
8. Per cent. efficiency = $\frac{\text{Energy usefully expended (Row 1)}}{\text{Energy actually expended (Row 7)}}$		70	77	72	74	75	82

The power losses along AB and AC are the same, say 1 w. The power loss along BC is greater than this say (1 + m)w. Energy lost while the water is heated along ABC is 1.Ab + (1 + m) bE = 1.AE + mbE.

Energy lost while the water is heated along AC = 1.AE. Thus the loss is greater along any path ABC than along AC *and the power used along the path AC gives the optimum power.*

Taking now the limits of the temperature range to be 80°F. and 180°F. as previously and the time in which the hot water is required to be 12 hours the optimum power and efficiency for these conditions are found in Table III.

(c) *Practical Operating Conditions.*

The efficiencies under a prescribed set of conditions are evaluated in Table IV, and depend greatly on what conditions of operation are specified.

In practice the heater would be refilled with cold water immediately after the hot water had been drawn off. The temperature and quantity of the hot water remaining below tap level, and the temperature and quantity of the water used for refilling, determine the initial temperature of the heating cycle.

TABLE III. EFFICIENCY UNDER OPTIMUM POWER FOR A 12-HOUR HEATING PERIOD

	Unit of Measurement.	Heater.					
		A.	B.	C.	D.	E.	F.
1. Energy required to heat water from 80°F. to 180°F.	kWh.	8.79	8.38	8.35	8.11	6.56	5.95
2. Energy lost in 12 hours heating. Ambient temperature 43°F.	kWh.	2.72	2.11	2.50	2.34	2.21	1.61
3. Total expenditure in 12 hours = (1) + (2).	kWh.	11.5	10.49	10.85	10.45	8.77	7.56
4. Optimum Power — (3) ÷ 12.	Watts	960	870	900	870	730	630
5. Efficiency under optimum conditions. Per cent.		76	80	77	78	75	79

TABLE IV. PERFORMANCE UNDER WORKING CONDITIONS

	Unit of Measurement.	Heater					
		A.	B.	C.	D.	E.	F.
1. Temperature of water immediately after refilling tank with water at 60°F.	°F.	80	65	91	83	86	86
2. Energy required to heat water up to 180°F. from temperature in (1)	kWh	8.79	9.64	7.43	7.87	6.17	5.59
3. Energy lost in 12 hours.	kWh.	2.72	2.11	2.50	2.34	2.21	1.61
4. Total expenditure of energy in one 12 hour cycle = (2) + (3).	kWh.	11.51	11.75	9.93	10.21	8.38	7.20
5. Optimum power input — (4) ÷ 12.	Watts	959	979	828	850	698	600
6. Efficiency = Energy required to heat available hot water from 60° to 180° F. ÷ Energy supplied in 12 hours. Per cent.		76	82	75	77	74	78

TABLE V. LOSSES DUE TO VARIOUS CAUSES

	Unit of Measurement.	Heater.					
		A.	B.	C.	D	E.	F.
1 Loss through insulating material at 180°F.	Watts	260	200	125	160	185	150
2. Loss from uninsulated surfaces at 180°F.	Watts	100	20	145	25	85	80
3. Loss by evaporation at 180°F.	Watts	Neg.	10	75	125	Neg.	50
4. Total Power Loss at 180°F. Ambient Temperature 43°F.	Watts	360	230	345	310	270	280

Neg. = Negligible.

Obviously losses (1) and (2) can be reduced only by attention to insulation ; loss (3) can be reduced by modification of the design of the tank outlet to reduce evaporation.

The operating conditions chosen are as follows :—

Ambient Temperature	43°F.
Hot water temperature	180°F.
Temperature of water used for refilling	60°F.
Draw off times	Every 12 hours, say 6 a.m. 6 p.m.
Amount drawn off	All available hot water.
Input power	Optimum power for each particular initial temperature and 12 hour heating.

(d) *Losses.*

Some of the figures in Table I enable an estimate to be made of the order of losses due to various causes. The most important of these are :—

(1) Loss through the insulating material.
(2) Loss from those parts of the outer surface not insulated.
(3) Evaporation.

If the extra insulation completely prevented loss from the surface covered by it, the difference between the maintaining powers at 180°F. with and without this additional insulation would give the loss due to this surface.

The evaporation loss may be calculated directly from the measured amount of evaporation.

CONCLUSION

Under practical conditions the heaters are seen to require a minimum wattage to obtain efficient heating. An input of 750 w., with conditions specified in the text, is insufficient in all but two cases for the temperature to reach 180°F. in 12 hours. Too low power is most probably the source of any complaint which may have arisen.

The efficiencies are seen to be between 70 per cent. and 82 per cent. Had an upper temperature limit higher than 180°F. been chosen the defects in design would have become more evident and the efficiencies would have been lower. Tables IV and V show that the efficiencies of all makes can be improved by better construction and by a choice of size and wattage better suited to the exact purpose for which the heater is intended.

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THE MEASUREMENT OF MILK VOLUME

By W. G. WHITTLESTON and S. A. VERRALL, Ruakura Animal Research Station, Department of Agriculture, Hamilton

(*Received for publication, 26th September, 1947*)

Summary

A labour-saving, milk-measuring and sampling apparatus is described. Tests showed it to be as accurate as the normal bucket and weighing procedure.

THE recording of daily milk weights or volumes is frequently required by workers investigating the problems of dairy cow production. The present paper describes a method developed at the Ruakura Animal Research Station.

The only really accurate way of determining the production of a herd of cows is to record milk weight and percentage of butterfat for every cow at every milking. In New Zealand where the releaser type of milking machine is in general use, this involves the use of individual vacuum buckets, the contents of which must be weighed and sampled. Such a procedure is inconvenient as a vacuum bucket upsets the normal running of a releaser plant and extra labour is required, thus making accurate recording of milk yields both laborious and expensive.

APPARATUS

One method of determining the amount of milk delivered by a cow is to run the milk from the teat cups of the milking machine into an evacuated chamber placed on a spring balance, so directly measuring the weight of milk produced. This is the method employed in the English Gascoigne Auto Recorder. During the war period we were unable to obtain spring balances of adequate accuracy, so that the direct weighing method was not developed but attention given to the direct volume measurement method. This has some advantages, particularly when the apparatus is required to supply a well-mixed sample for analytical purposes.

The apparatus to be described was designed to eliminate vacuum buckets on the floor of the shed, do away with extra handling of the milk, give an accurate reading of milk weight and take a satisfactory sample (Fig. 1). Further, the operation is simple and almost automatic, thus making it possible to record milk yields without extra labour in the shed.

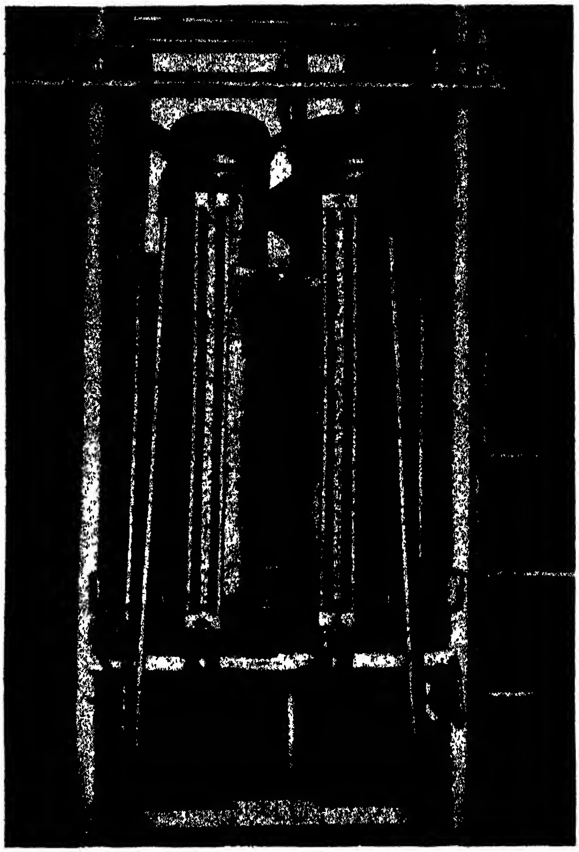


FIG 1.—Two milk-measuring and sampling units in position in the bail.

The procedure in operating the apparatus is as follows: The milk flows from the droppers into the measuring cylinders where the weight is read off from a gauge glass when milk flow has ceased. By using water in the gauge glass, the reading is easy and accurate. The milk is agitated by a stream of air bubbling through it from the bottom of the cylinder, and finally the mixed milk is drawn off, a burette being filled by the milk on its way to the milk pipe. All the measuring cylinders are emptied by the milk pipe, the milk being bulked in the vat of the machine after passing through the releaser. The sample is held in the burette, to be drawn at leisure, while the next cow is milking. All traces of the sample are finally blown from the burette into the milk pipe before the next sample is taken.

The following is a description of the new measuring unit:

Fig. 2 shows the general layout of the device. Milk enters by tube (a) the flow being directed downwards against the wall of the can by slot (b). At (c) is a small draining well into which the bottom end of the drain tube (d) opens. The well is closed by the rubber stopper (e) which is removed when the cleaning operations are finished after milking. Tube (f) leads via the rubber loop (g) to the gauge glass tube (h). The top of the gauge glass opens into the main cylinder. The gauge connecting loop (g) is left full of water after washing prior to milking.

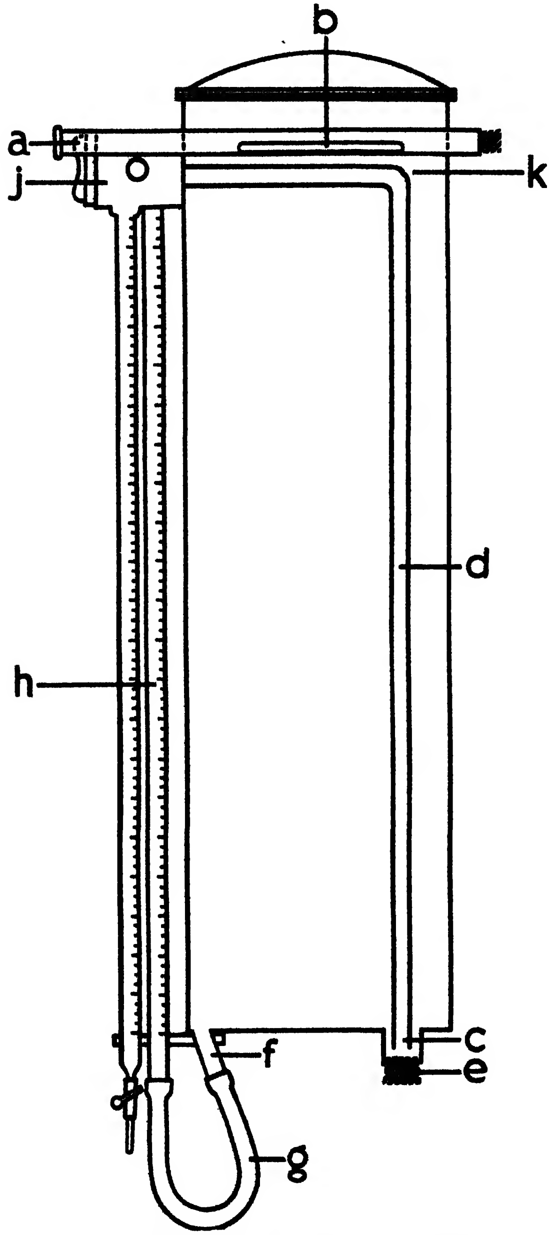


FIG. 2.—Schematic diagram of the device.

This water causes no serious errors in measurement and makes the reading of the level much easier than by using milk in the glass tube. At (k) there is a $\frac{1}{16}$ in. (approximately) air leak hole. The object of this air leak is to break up the milk-stream during the draining process. This results in turbulence in the valve and causes the burette to fill readily and uniformly.

All operations are controlled by valve (j), details of which are shown in Fig. 3. Fig. 4 shows a schematic sketch illustrating the action of the valve. The dotted line represents the port on the rotor; the dotted circle represents the air leak hole in the rotor. The stator ports are as follows:—(A) Connects to the draining tube reaching to the bottom of the draining well (c); (B) connects straight through to the space above the milk in the can; (B^1) similar to (B); (C) connects to the sampling burette; (D) connects to the milk pipe of the milking machine.

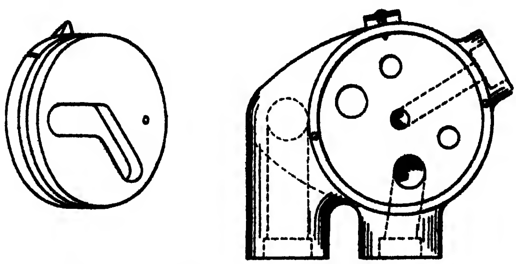


FIG. 3.—Details of the control valve.

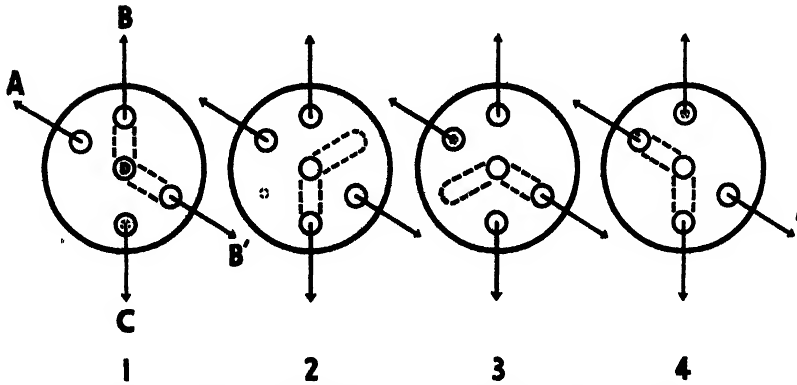


FIG. 4.—Sketch illustrating the action of the control valve.

The sequence of operations is as follows:—

Milking position.

In this case the vacuum from the milk pipe is connected to both ports B and B^1 while air is admitted through the leak to the burette, so enabling the sample to be withdrawn. The drain port is closed.

Reading position.

This shuts off the cylinder from the vacuum line. The object of this is to cut off the pulsations almost inevitably present in the machine vacuum supply and which tend to cause a slight swing in the milk level, so making the reading of the gauge glass difficult. In this position any milk retained in the burette may be drawn over into the milk pipe by opening the clip at the bottom.

Agitation position.

The vacuum is now connected to the top of the can while the air leak connects to the draining tube. This results in a current of air being bubbled through the milk producing enough agitation to give thorough mixing. Agitation for five seconds is adequate.

Draining and Sampling position.

The vacuum port in this position connects simultaneously to the drain tube and the sampling burette while the air leak connects to the space above the milk. As the milk is drained off, a small fraction of it collects in and fills the burette. When draining is complete as judged from the gauge glass or a "sight glass" on the drain lead, the valve is turned to position 1 when the sample can be drawn from the burette.

General construction.

The valve unit is made of cast brass with well-machined bearing surfaces. After many months of use no trouble due to leaks has been experienced. A simple retaining mechanism for the rotor consisting of a 14 G. brass wire spring, makes it possible to remove the rotor after cleaning, so ensuring adequate ventilation of the tubes between milkings. The burette and gauge tubes are of Pyrex glass. Earlier models had a paper scale fixed to the back of the glass and coated with cellulose acetate varnish. The later units have a scale engraved on the metal protecting frame which partly surrounds the glass tube. Scales must be individually calibrated owing to small variations in the diameter of the tinned copper cylinders.

OPERATION

Under normal milking shed conditions the device has proved quite satisfactory. Having the simple sequence of operations effected by a single valve it is possible for the normal shed-hand to operate it without difficulty. It is as accurate as the normal bucket and weighing procedure and there is no extra labour required above that involved in operating the normal releaser type of milking plant. Cleaning by filling with hot caustic soda solutions which are agitated by air admission appears to be quite satisfactory. In one experimental model, provision was made by an additional valve arrangement to drain the wash solution through the gauge tube, so cleaning it out thoroughly. This can be done by fitting a two-way tap to the top of the gauge, one connection being to the top of the can, the other straight to the milk pipe. As this is an additional complication it was cut out, a thorough cleaning being possible without it.

ACCURACY

The test was carried out first by milking into the measuring unit and noting the gauge reading, and secondly by running the milk over into the normal vacuum bucket, where it was then weighed. The following data give the results of comparisons of the new technique with the bucket weighing procedure.

Number of trials	=52
Mean for cylinder readings	=8.306 lb.
Mean for bucket weighings	=8.295 lb.
Difference between means	=0.011 lb.
Standard error of difference between means	=0.016 lb.

SAMPLING

In order to check the mixing and sampling mechanism of the measuring unit, samples from the burette and from the bucket into which the milk was run and mixed in the usual way were analysed for butterfat. The results of some of these analyses, expressed as percentage of butterfat are given below. All samples were taken in duplicate and each sample was divided and analysed in duplicate.

	Percentage Butterfat	(Means of 45 trials)
Cylinder—Sample 1	5.160	5.156
„ 2	5.154	5.280
Bucket —Sample 1	5.207	5.234
„ 2	5.251	5.224
Mean for all cylinder tests	5.188	
Mean for all bucket tests	5.229	
Difference between means	0.041	
Standard error of difference between means	0.045	

Generally the results indicate that the device is as accurate as the normal weighing and sampling procedure.

ACKNOWLEDGMENTS

The writers wish to express their gratitude to Mr. D. J. Allen of this laboratory who prepared the original working drawings of the control valve shown in Fig. 2, and made many practical suggestions during the construction of the apparatus, to Mr. B. H. Miller for drawing Fig. 2 and to Mr. J. B. Strickland for Fig. 3.

THE OTAIHANGA FAULTED OUTLIER AND NOTES ON THE GREENSAND DEPOSIT.

By E. O. MACPHERSON, New Zealand Geological Survey

(Received for publication, 30th January, 1948)

Summary

A faulted outlier of covering strata, recently discovered near Paraparaumu, is described.

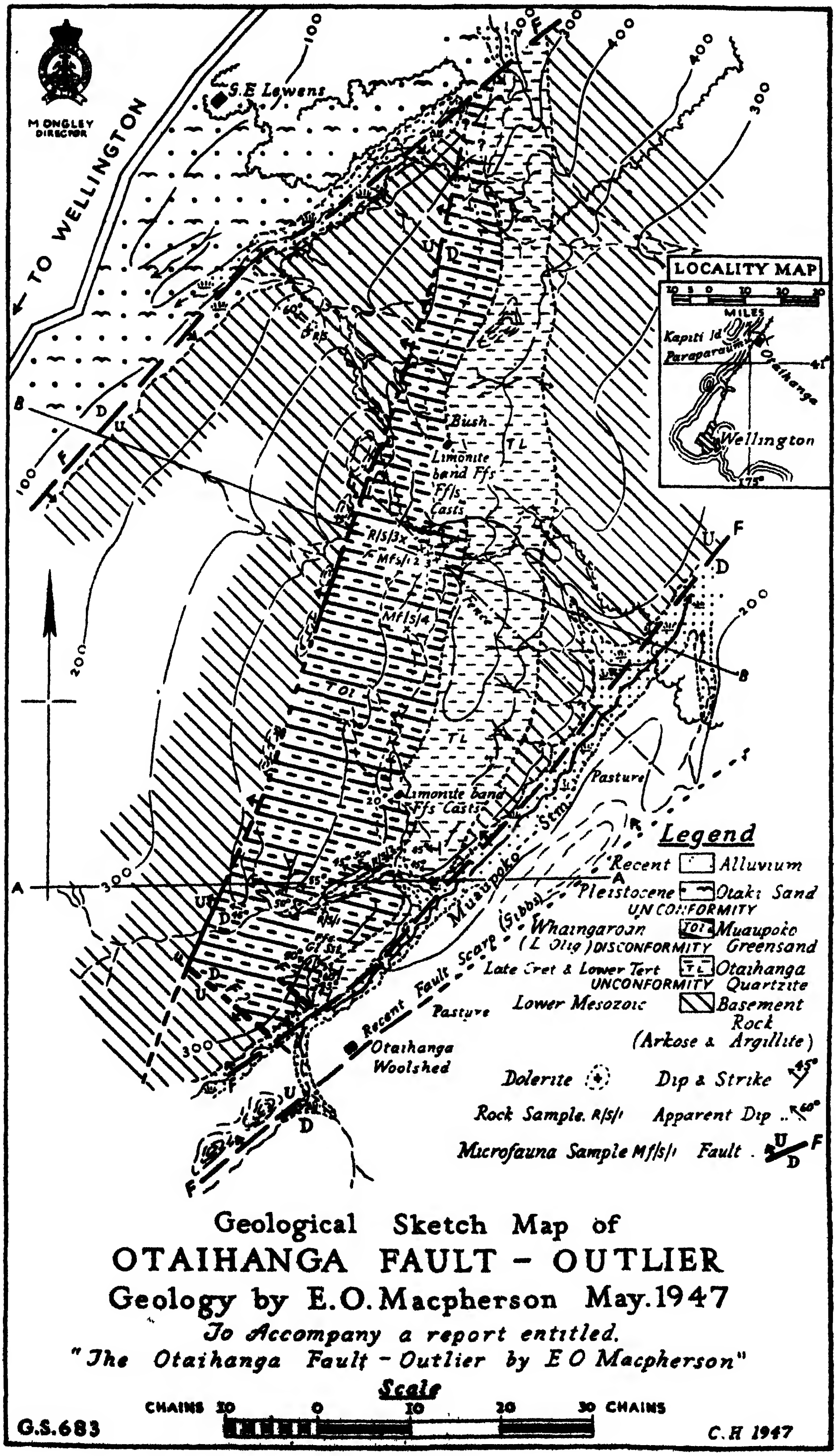
Quartzites which occupy the lower part of the section are disconformably overlain by 600-800 ft. of glauconitic sandstone of Whaingaroan age (Lower Oligocene) and may be of use as gannister.

The quantity, accessibility and freedom from overburden suggests that the glauconitic sandstone can be used commercially.

The uses of glauconite as a source of potash in agriculture, and in the paint industry are discussed.

INTRODUCTION

AN interesting outlier of Lower Oligocene greensand and older sedimentary quartzite was recently discovered in the hills 1½ miles northeast of Paraparaumu village. Fossil casts were found in the area by local residents, who communicated this information to the New Zealand Geological Survey, and a search for fossils led to the discovery. Later the district was mapped by the writer, and this work revealed the extent of the glauconitic sandstone and sedimentary quartzite described in the following account.


M. ONGLEY DIRECTOR
TO WELLINGTON
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Limonite band Ffs Casts
Muaupoko Stm
Recent Fault Scarp (Gibbs)
Otaihanga Woolshed
Legend
Recent
Alluvium
Pleistocene
Otaki Sand
UNCONFORMITY
Whaingaroan
(L Olig) DISCONFORMITY
Muaupoko Greensand
Late Cret & Lower Tert
UNCONFORMITY
Otaihanga Quartzite
Lower Mesozoic
Basement Rock (Arkose & Argillite)
Dolerite
Dip & Strike
Rock Sample. R/S/1
Apparent Dip
Microfauna Sample Mf/S/1
Fault
Geological Sketch Map of
OTAIHANGA FAULT - OUTLIER
Geology by E.O. Macpherson May. 1947
To Accompany a report entitled.
"The Otaihanga Fault - Outlier by E O Macpherson"
Scale
CHAINS 10 0 10 20 30 CHAINS
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GEOLOGY

The area was mapped by pace traverse and cross bearings; the map will be much improved if instrumental methods are used. The rocks were subdivided into four groups: (a) Basement arkose and argillite; (b) Otaihanga quartzite; (c) Muaupoko greensand; (d) Otaki sand. The distribution of these rock units is shown on the accompanying map and brief descriptions are added below.

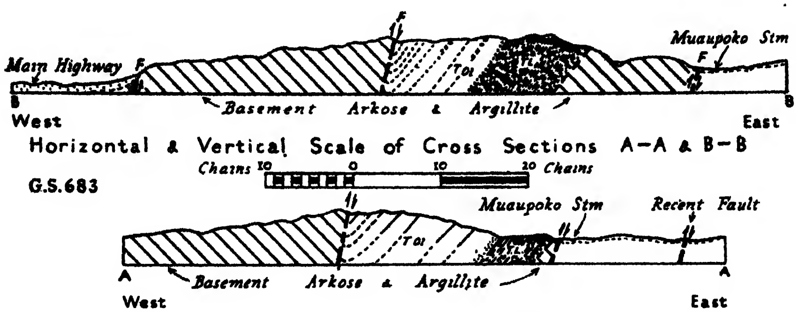

FIG. 2

(a) *Basement Arkose and Argillite:*

This survey did not attempt to discover the complex structure or succession of the basement. Rocks rich in feldspar and quartz predominate, with bands of argillite and rare dark brown to black chert layers. On the eastern part of the area the strike is north or a few degrees east of north, with the dip everywhere high and erratic in direction. Along the west side, attitudes in the basement are also erratic, and the beds are brecciated and contorted. The basement rock is faulted along this part of the area.

A fine-grained, dark brown, decomposed dolerite was noted in the basement arkose, 10 ch. up the small stream that drains the western slope; this rock outcrops obscurely up the south slope of the stream, just at the break in topography. The outcrop is shown on the accompanying map. A similar looking rock, but not specifically identified as igneous, was seen in the south part of the area, 6 ch. west of Otaihanga Woolshed and 100-200 ft. south-west along the slope of the spur. Possibly this igneous material was injected along the main fault that limits the area on the west; it may be much younger than the basement arkose and argillite.

(b) *Otaihanga Quartzite:*

A major unconformity separates this group from the basement arkose; here a long time-break is represented. The quartzite rests on deeply weathered basement and at the few localities where it is poorly exposed, the basement seems to have been planed; however, exposures of the basement contact are nowhere well shown in the area.

The Otaihanga sedimentary quartzite is a light grey, strong rock, consisting almost entirely of sub-rounded and angular quartz grains firmly cemented by secondary quartz. Very rarely there are lenses or layers not more than 2 in. to 1 ft. thick of well shaped, smooth quartz pebbles but these layers do not persist along the strike, and are more noticeable in the basal and upper parts of the quartzite section.

In places, especially at the upper contact with the overlying Muaupoko greensand, the quartzite is much stained with iron oxide. Generally, however, the mass of the rock is practically free from iron stain. Small lignitic shale fragments were noted in the upper part.

The quartz grains are sub-angular, and from 0.2 mm. to 0.44 mm. long ; they generally have undulose extinction and many contain minute inclusions. The grains are either welded or re-cemented by secondary interstitial quartz. The sample microscopically examined was composed almost entirely of quartz, feldspar was not detected, and iron-staining was rare.

The distribution is shown on the accompanying map ; the quartzite forms a prominent strike ridge along the eastern part of the area and weathers to prominent sharp outcrops (Figs. 1 and 2). The attitude can rarely be measured, but a few observations in the southern part show strike around 5°-10° east of north, with dips of 45°-65° to the west, and this general attitude is assumed to apply throughout. The distribution indicates a general south strike, with a tendency to swing to the south-west in the south.

Through the forested part of the area, the quartzite is difficult to trace, but a prominent rusty limonitic band in the basal part of the overlying greensand helps to place the top of the quartzite there.

The Otaihanga quartzite was deposited under rather special conditions during the late Cretaceous or early Tertiary, when the land was much reduced. The quartzite resembles the " chinamen " boulders and quartz grits of Central Otago, the grits and quartz conglomerates of the Brunner Beds (P. G. Morgan and J. H. Bartrum, 1915) and the quartzose conglomerate and grit of Parapara, Aorere Valley, and Quartz Range (J. M. Bell, 1907). The Otaihanga quartzite may be a fluvial deposit, but this is not yet established and depends mainly on its similarity to the quartz sediments in the regions mentioned above, that are either proven terrestrial sediments or thought likely to be so.

The age can only be placed by the overlying greensand as pre-Whaingaroan (i.e., pre-lower Oligocene), but a disconformity separates the two groups.

Sediments of this special facies do not occur in the late-Cretaceous—lower Tertiary marine groups on the East Coast, excepting along the foothills from middle Canterbury and southward. It therefore seems more reasonable to relate the Otaihanga quartzite with the quartz grits and conglomerates of the Takaka-Collingwood region, where they also form the basal group, and are overlain by argillaceous limestone of lower and middle Oligocene age.

(c) *Muaupoko Greensand :*

A remarkable development of greensand disconformably overlies the Otaihanga quartzite ; at the section of reference, up the westward-heading branch of Muaupoko Stream, this group of beds is about 850 ft. thick. The basal member is a prominent, rusty, limonitic layer, 20-30 ft. thick, containing casts of mollusca and thin lenses and occasional pebbles of well-shaped quartz. Overlying this basal member are several 4-10 ft. layers of weakly glauconitic fine-grained, grey sand, and silt with humic staining ; this in turn is overlain by the main section of the Muaupoko greensand.

Angular discordance was not seen at the contact, but as the latter is nowhere well exposed, there may possibly be an unconformity between the quartzite and overlying greensand. It is thought that if folding did occur it was slight, and the quartz pebbles in the basal limonitic member, the contrast in the sediments, and the sudden influx of the molluscan fauna are evidence for disconformity.

At the section of reference, the greensand is not continuously exposed, and grey sand layers may break the apparent continuity of the thick greensand ; however, such barren, grey sand members, although searched for, were not observed.

Alternating hard and soft bands that strike north and dip 45°-60° west make up the section ; the harder bands stand out as strike ridges and the softer and more richly glauconitic form slight depressions.

A second section poorly exposed was examined 3,000 ft. north of the section of reference ; the greensand appeared to be about 600 ft. thick. Still further north, grey sand and mudstone layers are bedded with the greensand, showing lateral variation north along the strike.

The Muaupoko greensand extends 6,500 ft. north, but along the northward extension it thins to 200-300 ft. and the upper part of the section cuts out along a north-east thrust fault, which limits the group to the westward (Fig. 3). Outcrops are obscured in the north part by forest.

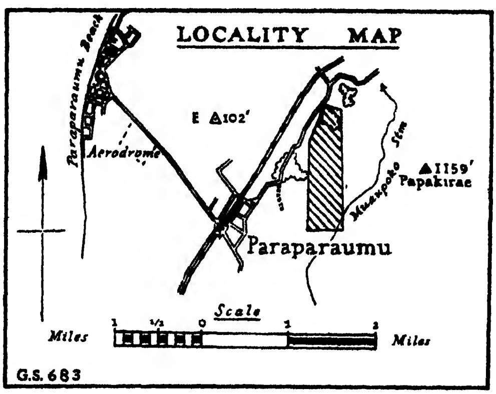

FIG. 3

Very many fragments of greensand were examined by hand lens and all appeared rich in glauconite, some loosely, others firmly cemented by quartz ; the cement was rarely lime carbonate. One sample considered medium grade from field experience was concentrated by electromagnet and found to contain 76.9 per cent. glauconite ; the residue consisted of angular and sub-angular quartz grains. Some glauconite occurs as round smooth pellets which have a minimum of interstitial quartz cement and which may have been transported to the site of deposition. Much glauconite occurs, especially in the lower grade greensand, as interlocking angular grains of glauconite and quartz. The grains of quartz are sub-angular and not smooth. Glauconite grains shaped as internal casts of foraminifera were not noted.

The percentage of potash was determined for three samples collected at random, but with the intention of illustrating low, medium, and high grade greensand. The results are recorded below :—

	N. 880/1	N. 880/2	N. 880/3.
Potash (K_2O) per cent.	5.47	6.05	5.76

These percentages appear high, being about only 1 per cent. below the average of seven samples of pure New Zealand glauconite studied by Hutton and Seelye (1941) and higher than bulk samples (4.2 per cent.) from the Bracklesham Beds (Oakley, 1943, p. 25). Hutton and Seelye (1941) record that K_2O content for fresh glauconite varies from 4 to 8 per cent.

The origin and conditions of deposition of glauconite have been much studied. Oakley (1943, p. 4) citing Hadding, records the following : Glauconite is always marine, always sub-littoral, and always a shallow sea formation which as a rule was formed in agitated water under decreased deposition of fine detritus ; it is most abundant after periods of negative sedimentation, is never formed in oxygenous water and is to a large extent allothigenous (i.e., not found where deposited). Probably glauconite is mainly formed between 10 and 100 fathoms.

From the work of J. Takahashi (1939) it is likely that glauconite is formed by diagenesis, and that the material from which it is formed is variable ; clay, fragments of volcanic glass, opaline silica, feldspar, and micas are now known to form glauconite given the correct environment.

The Muaupoko greensand is thick and it seems necessary to assume slow sinking with continued glauconitization at the site of deposition, or bottom currents conveying the glauconite to the site of deposition from where it was formed. A proportion of the soft glauconite grains and pellets are rounded and smooth, with dull surface polish suggesting that they were conveyed by bottom currents. This by no means applies to all the glauconite in this deposit, much of which occurs as angular interlocked particles, associated with quartz grains which are also quite angular and have no obvious surface polish. Seemingly this variety of grain was formed at the site of deposition.

Several mudstone and silt samples from bands in the greensand were collected for micro-faunal analyses. These samples were all from about the same locality, which is shown on the map. One yielded a small fauna ; Dr. H. J. Finlay's remarks are appended below. The macrofauna samples were collected from about the middle of the greensand ; the upper beds may be still younger, possibly Waitakian (Middle Oligocene).

(d) *Otaki Sand :*

Extending along the north-west margin of the area mapped, are well consolidated sands, which are similar to sands described by G. L. Adkin (1910), and named the Otaki Sand by Cotton (1919). This group will not be discussed further.

STRUCTURE

The distribution of this outlier is mainly controlled by faults of various age. As noted, the attitude of the beds cannot be well observed, but from the regional distribution and measurement of a few bedding planes, the strike is approximately north with dips of 40°-65° west, with, perhaps, higher dips in the north part. The outlier can be regarded

as a block of basement arkose with its covering strata, rotated westward, along a north-south axis and limited to the west and south-east by faults.

There is no clear section exposing the main fault that limits the Muaupoko greensand on the west, and whether it is a thrust or a tension fault cannot be stated with confidence. There is, however, a suggestion that the basement rock on the upthrow side slopes up-valley where the fault crosses Muaupoko Stream. There is also some evidence that this fault cuts across the strike of the greensand, making a low angle with the strike, and progressively eliminating upper members of the greensand. This evidence may indicate an upthrust fault with increasing throw northward.

A north-east trending fault, obscured by alluvium along the Muaupoko Valley, defines the area on the south-east. Apparently this fault is much later than the main thrust fault along the west, for it controls the north-west side of Muaupoko Valley and if projected south-west it disrupts the Otaihanga quartzite. Earlier movements, of about the same age as those of the main thrust fault, may have taken place along this south-east boundary.

The north-east trending fault that defines the hills from the low country to the west is a regional fracture in this part of Wellington province. Mr. G. L. Adkin has recorded and described it in a recent paper not yet published. It extends for only a short distance through this area and is marked by fresh scarp facets, which some observers have ascribed to cliff cutting by waves. Apparently this fault disrupts the northern extension of the greensand and quartzite; a pre-Otaki Sand fracture, is accepted. Apparently it is tension fault connected with late Pliocene and Pleistocene collapse.

A recent fault, trending north-east along Muaupoko Valley, was discovered by Mr. H. Gibbs of the Soil Bureau during his study of the soils. The surface trace is fairly distinct and shows an up-step of 10-20 ft. on the north-west side (Fig. 4).

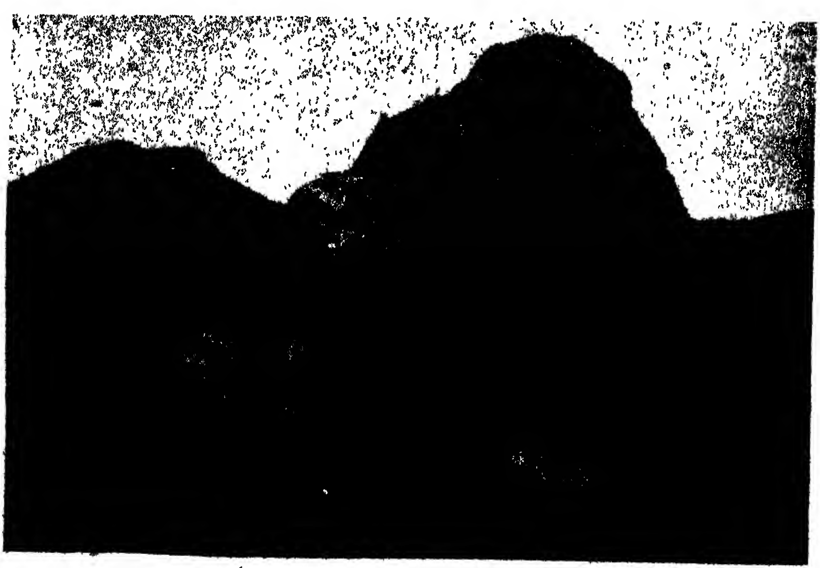

FIG. 4.—Steep westward dip on Otaihanga quartzite.

It will be noted that three faults of this area, the main west upthrust fault, the south-east boundary fault, and Gibbs's recent fault, although widely separated in time, all appear to be upthrown on the west and north-west. The fault along the north-west part of the area is apparently downthrown to the north-west.

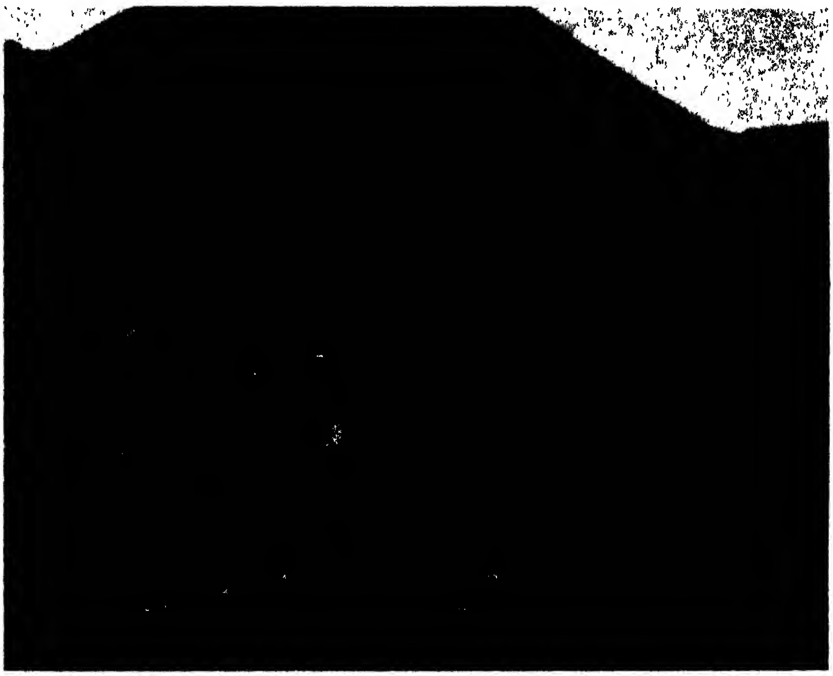

FIG. 5 -Westward dipping quartzite controlling ridge. View northward; Otaihanga faulted outlier.

USES OF GLAUCONITE

Glauconite has been used as a source of potash, as a fertilizer, in paint, and as a water softening mineral. The Muaupoko greensand has specially favourable advantages such as (a) substantial quantities relatively free from other contaminating minerals; (b) excellent opencast mining conditions, such as absence of overburden and height of glauconite deposit above drainage level; (c) its accessibility as it is only 1½ miles from Paraparaumu Railway Station and less than one mile from the main highway.

The above favourable conditions indicate that research into some of the uses noted are justified. J. J. S. Cornes of the Dominion Laboratory was, therefore, introduced to the problem and has done preliminary work, mainly with the object of making silico-phosphate fertilizer, by fusing dolomite, rock phosphate, and glauconite to make a citric soluble slag. He has kindly given me an account of his preliminary results; they appear to have considerable promise. The research is still in progress, and he intends to publish his results when they are further advanced.

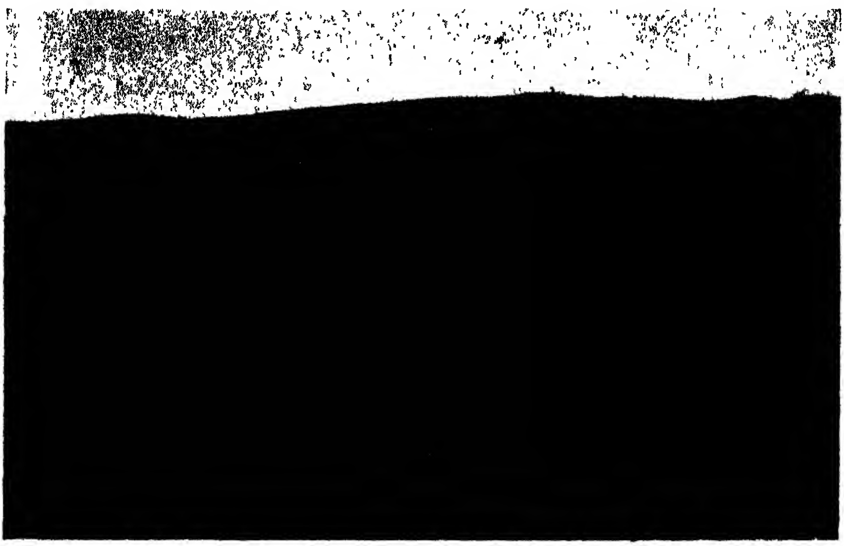

FIG. 6.—Subdued surface on Muaupoko greensand, with position of faulted west boundary shown. The distant ridges are of greywacke. *(Photo. by M. Ongley)*

Potash :

Glauconite has never been an important source of potash, the world market being mainly supplied by water soluble potassium salts. Until about 1930 most of the world depended on a foreign government-controlled monopoly for supplies, but of late years high grade potassium salts were discovered in U.S.A. Since World War II, the very important world source of potash of Stassfurt, formerly owned by Germany, is now included in the U.S.S.R. zone.

During the period 1918-1919, potash was extracted from the glauconite sands of New Jersey (Oakley, 1943, p. 18). The process used was to mix the sand with lime and water to form a cream and extract with steam under pressure in an autoclave for several hours at 200°c. The product was leached with water to extract the potash as potassium hydroxide. The process is discussed in U.S. Patent 1234626 (Charlton and Kaolin Products Corporation).

Other methods of extracting potash from glauconite were tried out in U.S.A. during the last war (Mansfield, 1922), and according to Oakley (1943) further experiments are now in progress in England. The time therefore may not be far distant when glauconite can be used as a commercial source of potash ; and in view of the present world potash control, countries deficient in potash reserves should study such possible sources as glauconite.

Agriculture :

In the south of England, Belgium, France, and U.S.A., greensand has been opencast mined for many years, and used locally as a fertilizer for hop fields, orchards, and market gardens ; it has probably functioned as a mild potassic fertilizer. Oakley (1943, p. 18) points out that many strawberry gardens are situated on the glauconitic Bracklesham Beds in Surrey, probably owing to the practical experience of growers that

the strawberry thrives on the glauconitic soil. In Western Australia it is found that oranges thrive on outcrops of Gingin glauconitic sand (Simpson, 1934, p. 394), and in this country remarkable crops of potatoes are grown in the Willowbridge district, on soils derived probably from the Waihao greensand.

Generally, however, for most crops and soils, glauconitic sand does not give much obvious response, and the supposed beneficial effects on sandy and clay soils may be owing to an improvement in soil texture, rather than potassic response. Nevertheless the rapid weathering of glauconite to "limonite" on exposures of Muaupoko greensand shows that potash is probably slowly released and under suitable conditions may be available. According to Mansfield (1922, p. 129) only a very small proportion of the potash in glauconite is water soluble, not more than 0.06 per cent. in glauconite sand containing 7.72 per cent. K_2O. Much doubt therefore exists if untreated glauconite would have sufficient fertilizer value to be transported. Field trials carried out in New Zealand in 1941 (Anon: *N.Z. J. Agr.*) on potash deficient soils produced no significant improvement.

From these practical results and experiments, further research is required if we wish to find out what determines the availability of the potash in glauconite. It seems probable that from such research, either here or overseas, that a method of treating greensand will be discovered. It is important for countries like New Zealand which have no better potash deposits. It also seems worthwhile to do pot experiments and field trials with glauconite to learn just what varieties of soil and crops benefit from its use.

Paint Industry:

Ground glauconite yields a powder of pleasing green hue; but it is generally considered useless as a green paint pigment, owing to its low refractive index, low tinting strength and low degree of permanence. Experiments to test its use for colouring tennis courts and landscape gardens showed that it lacked fastness on exposure to rain water.

On exposed surfaces glauconite quickly weathers to a rusty coloured limonite (hydrated ferric oxide); if finely ground and calcined at various temperatures and air supplies, a rich red-brown pigment can be made, and a wide range of browns, reds, and purples can be obtained.

Glauconite can also be used in its raw state as a substitute for "green earth" (celadonite) and used by paint manufacturers as an adsorbent or fixing base for aniline colours. Its liability to oxidation and dark colour are defects in this connection but it has been used as an adsorbent for green dyes in making distempers (Simpson, 1934, p. 394).

Oakley (1943, p. 20) discusses interesting adsorbent tests using Knaphill glauconite and malachite-green. These tests showed that raw ground glauconite could adsorb 5-7 per cent. of malachite-green, and the filtered lime green with 5 per cent. dye proved fast on washing with water. The glauconite from that locality, at least, is a very suitable "green earth" for use in making lime colours.

Formerly glauconite, concentrated from greensand and sold under various trade names, was extensively used for softening water by base-exchange; but now synthetic zeolites and carbonaceous zeolites, which have higher base-exchange capacities, are becoming widely used. Treated glauconite is still used, and an extension of the work commenced

by Cornes (1941) is indicated. This work could follow the lines of gradings, cleaning, and chemical treatment, designed to give more open structure. Owing to its softness, glauconite is liable to disintegrate after repeated regeneration. At one time the practice was to heat to 700°c. to case-harden the grains. It is now known that heating reduces the base-exchange capacity, (Ingleson, H. and Harrison, A., 1941, p. 81) and the growing practice is to harden the grains by chemical treatment, which also enlarges the base-exchange capacity.

According to Simpson (1934, p. 394) activated glauconite has been used in U.S.A. for "humanizing", cows' milk for diet of infants and invalids. By passing the milk through a glauconite filter, about 20 per cent. of the calcium is removed, this results in the milk yielding a fine and more easily digested curd.

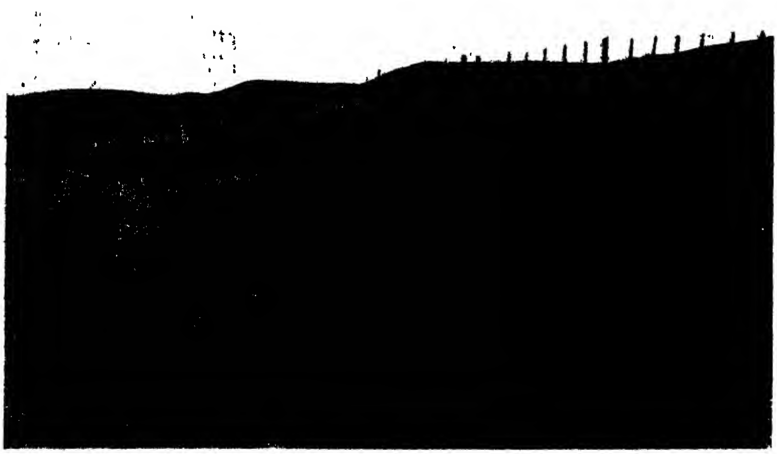

FIG. 7.—Looking south-west at Gibbs's recent fault scarplet, Otaihanga Valley. (*Photo. by M. Ongley*)

Quantity of Glauconite:

The occurrence and uses of glauconite have been discussed, but before closing this account it may be useful to give a rough estimate of the tonnage of greensand in the Otaihanga area.

The following estimate is based on geological data and is of course subject to the disabilities attached to such estimates. If this is fully realized, such an estimate can be a useful guide.

If we leave out the northern part of the Muaupoko greensand (see map), i.e., where it thins and has interbedded mudstone and sandstone members, and is obscured by forest, there remains a southern portion about 3,300 ft. long where the greensand is fairly well exposed. In this part, two sections indicate an average thickness of 600 ft. of greensand, apparently almost free from interbedded barren sandstone and silt members. The average height of the deposit above drainage level is taken as 300 ft. These factors give a volume of about 22 million cu. yd. As moisture content, bulk density, and average weight per

cubic foot have not been determined, there are no reliable data to convert this volume into tons in place. If this mixture of glauconite and quartz is assumed to be sandstone (150 lb. per cu. ft. in place) the tonnage =

$$\frac{3300 \times 600 \times 300 \times 150}{2240} = 40 \text{ million tons.}$$

As noted elsewhere the greensand contains 50-90 per cent. glauconite with 5.5 per cent. K_2O.

SILICA REFRACTORIES

Some layers in the Otaihanga quartzite are almost pure cemented quartz with no feldspar or other mineral contaminant and with practically no iron staining. This rock can be classed as ganister, and could be crushed and moulded into silica bricks or sawn into blocks for furnace linings.

Two samples (N. 880/4 and N. 880/5) were taken for analysis, and the Dominion Laboratory has kindly supplied the following results.

Quartzites.

N. 880/4 — G.S. 0/1, White sample.
N. 880/5 — G.S. 0/2, Reddish sample.

Of the two samples collected by Mr. E. O. Macpherson, the white one, No. 880/4, was the more fully analysed, with the result :—

	Per cent.
Loss at 105°c.	0.28
Further loss on ignition	0.57
Total loss	0.85

Further analysis is reported as percentage of ignited weight.

	Per cent.
Fe_2O_3	0.50
Al_2O_3	1.65
TiO_2	0.10
CaO	trace
MgO	trace
Alkalies (Mainly K_2O)	0.35
SiO_2 (By difference)	97.40
	100.00

Requirements of Ganister :

U.S. Bureau of Standards recommends 97 per cent. SiO_2 and not much over 0.4 per cent. alkalies.

United States Geological Survey specifies 98 per cent. SiO_2; not more than 1.5 per cent. Al_2O_3, and stipulates that the material should crush to fine angular fragments.

Department of Mines, Canada (Cole, L. H., "Silica in Canada") 97.5 per cent. SiO_2, not over 1.5 per cent. Al_2O_3, nor over 0.75 per cent. other impurities, with grains that are splintery, sharp and heterogeneous in form and size. When moulded into brick and fired the material should expand and swell without perceptible cracking.

As far as chemical analysis is concerned, the above sample appears to satisfy the requirements reasonably well, with alumina very slightly on the high side.

Note :

In the case of the reddish sample, N. 880/5, where Total Loss on Ignition = 0.94 per cent. (cf. 0.85 above), the analysis, on ignited basis, compared as follows :—

	Per cent.
Total R_2O_3 (Fe_2O_3, Al_2O_3, TiO_2)	2.35 (cf. 2.25)
CaO	0.10 (cf. trace)
Total Alkalies (mainly K_2O)	0.55 (cf. 0.35)
SiO_2 (by difference)	97.00 (cf. 97.40)

It would appear that the main difference here consists in slightly more ferric oxide, and decidedly more alkalies, but that the material, by chemical standards, is still suitable for a fairly good siliceous refractory. Microscopic examination of the powdered material suggested that the potash may occur in feldspar grains or in impure interstitial clay rather than in mica or glauconite.

W. A. JOINER,
Dominion Analyst.

APPENDIX

NOTES ON THE MICROFAUNA FROM HILL ½ MILE SOUTH-EAST OF LEWIN'S FARMHOUSE, 1½ MILES NORTH-EAST OF PARAPARAUMU

By H. J. FINLAY

The original sample was collected from the mudstone (F. 6643) overlying the thick glauconite (G.S. 3374) and yielded the following species :—

Anomalinoides fasciatus (Stache)
Arenodosaria antipoda (Stache)
Cassidulina subglobosa Brady
Cibicides thiara (Stache)
Cyclammina incisa Stache
Discorbis scopos Finlay
Eggerella cf. *ihungia* Finlay
Eponides ecuadorensis G. and M.
Gaudryina reussi Stache
Gyroidina allani Finlay
Nodosaria longiscata d'Orb
Sphaeroidina bulloides d'Orb
Uvigerina maynei Chapman (common)
Vaginulinopsis hochstetteri (Stache)

The preservation of this small fauna is not good, and the only short-ranging species in it is *Uvigerina maynei*. No *Rotaliatina sulcigera* (Stache) was actually found, but the probabilities are that the age is Whaingaroan. A Duntroonian age is possible, but no specimens of *Notorotalia* either were found to check this. Other samples collected subsequently from the same and lower bands yielded either poorer faunas or nothing at all.

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GEOLOGY OF THE PIKE RIVER COALFIELD, NORTH WESTLAND.

By H. W. WELLMAN, New Zealand Geological Survey, Department of Scientific and Industrial Research, Greymouth

(*Received for publication, 14th October, 1947*)

Summary

A preliminary description and map is provided of a faulted outlier of coal measures and lower Tertiary marine beds on the crest of the Paparoa Range 20 miles north of Greymouth. The coal measures contain several million tons of bituminous coal, but the area is not easily accessible. The additional information provided by the beds at the crest of the range is critical in the interpretation of the geological history of the district. Not only does the outlier show that the coal measures and marine beds once extended over the range, but by containing beds thicker than corresponding beds on the flanks, it shows that deposition was more rapid at the crest than at the flanks of what is now the Paparoa Range. The total thickness was large, and this suggests that the Paparoa Range was the site of a lower Tertiary geosyncline which has since turned itself inside out so that what was once the deepest part of the geosyncline is now the axis of the range. Coal analyses support the stratigraphic evidence, the more deeply buried coal from the outlier being bituminous and considerably higher in rank than the sub-bituminous coal of the same age on the flanks of the range. The evolution of the coal field is illustrated by four cross sections, and coal analyses are given to show the change in the rank of the coal.

PREVIOUS DESCRIPTIONS

PIKE River Coalfield is the name here given to an isolated block of coal measures on the crest of the Paparoa Range about ten miles north of Blackball. The first report by Morgan (1911, p. 13) stated: "From information supplied by Messrs. T. Thompson (Buller County Engineer), Low (Seddonville), and J. Parsons (Charleston), it appears that one or more thick seams of coal outcrop in the watershed of the Porarari River in the south-eastern part of the Brighton Survey District. The outcrops occur at elevations of 1,500 ft. to 3,000 ft. above sea-level."

A more detailed description was given later by Henderson (1917, p. 204).

"A small outlier of coal-bearing strata, consisting of conglomerate, grit, and sandstone, isolated by crustal movements and denudation, occurs on the divide between the Porarari and Punakaiki rivers on the one side and the Big (Freeth) River on the other. Several outcrops are reported to occur in the Porarari fall, and one seam, of which the position is roughly indicated on the map (Geological map of Brighton Survey District). crops out near the crest of the ridge. The writer had no opportunity of examining this remote locality. The coal-fragments noted in the bed of Pike Stream and the main south branch of the Porarari River indicate that the seams consist of bituminous coal. Several square miles of apparently horizontally disposed and probably little disturbed coal-measure strata may here exist, and as some of the seams are reported to be of good workable thickness the area, in spite of difficulty of access, may yet prove worthy of commercial exploration."

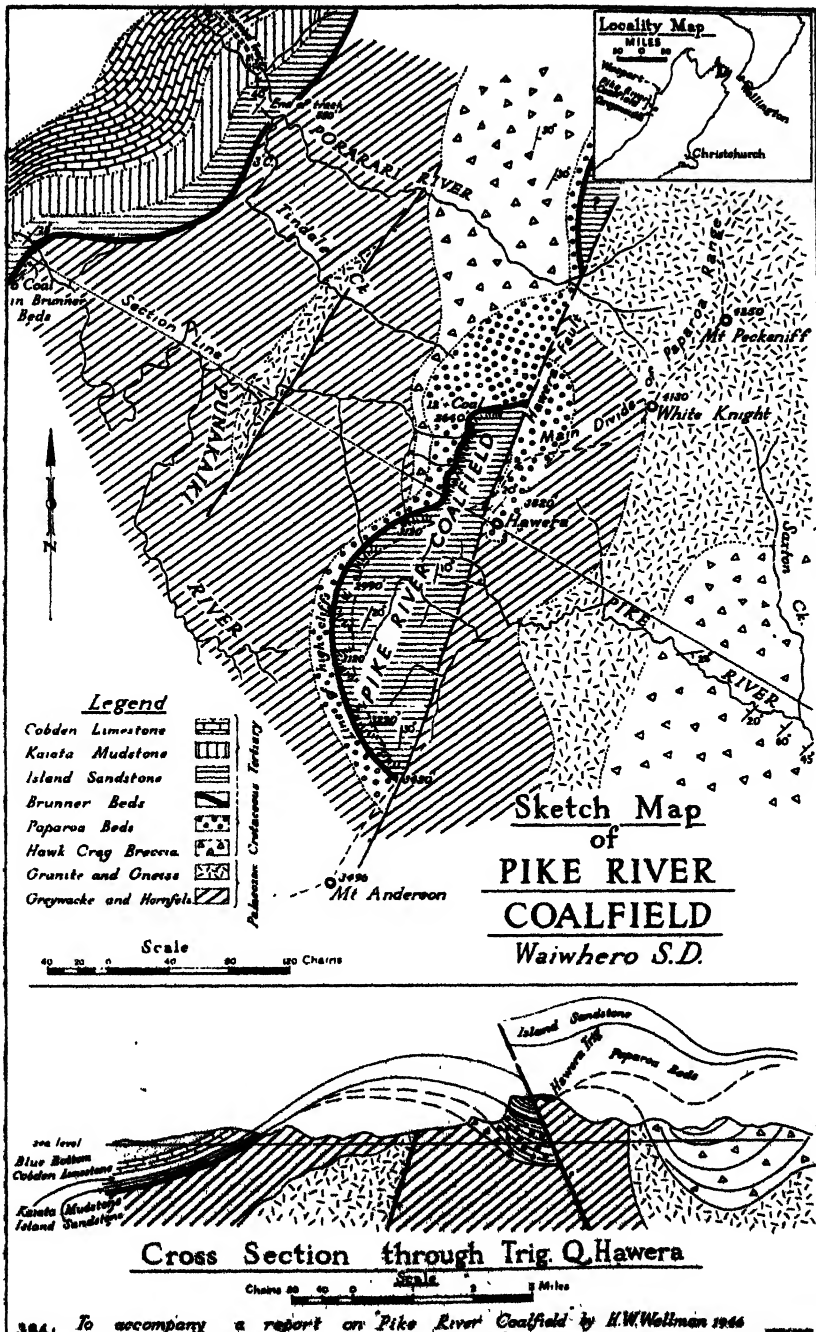

FIG. 1.—Geological sketch map and cross section of Pike River coalfield.

ACCOUNT OF ROUTE TAKEN AND ACCESS

During the weekend ending 17th March, accompanied by Mr. and Mrs. B. Tindale, I made a traverse of the Paparoa Range in order to visit the coalfield described above. A car road extends from Blackball along the east side of the Grey River to near the mouth of Big River where a branch road extends in for 4 miles, the first 2 miles of which are in good order. Big River was then followed for 4 miles to the junction of Pike Stream where we camped on the night of the 15th. On the 16th we followed Pike Stream for 2 miles beyond the junction of Saxton Creek; up to this point travelling was easy and the creek bed could be followed. The upper part of the creek is rough and gorgey and we left the creek to follow a well defined ridge which leads directly to trig. Q, (Hawera) 3,890 ft. The bush line was reached at 2.30 p.m. I spent the rest of the afternoon examining the area south-west of the trig. We camped the night above the bush line a few chains east of trig. Q. On the following day we followed the main divide of the Paparoa Range for just over half a mile north of the trig. and then attempted to make our way down to the head-waters of a large unnamed southern tributary of the Porarari River, which for convenience will be referred to as Tindale Creek. Both sides of the headwaters of this creek are flanked by steep bluffs and it took 4½ hours to reach the bed of the creek from the trig. The upper part of the creek flows in a wide open valley and travelling is good, but a mile from its head the stream enters a deep gorge through which it flows for 2 miles. It took 5 hours to negotiate this gorge. At the end of the gorge the stream takes a sharp bend and flows north-east for a mile along a wide open valley to join the Porarari River half a mile from the end of a formed track. The track was followed out to the coast at the mouth of the Punakaiki River which we reached at 9.30 p.m.

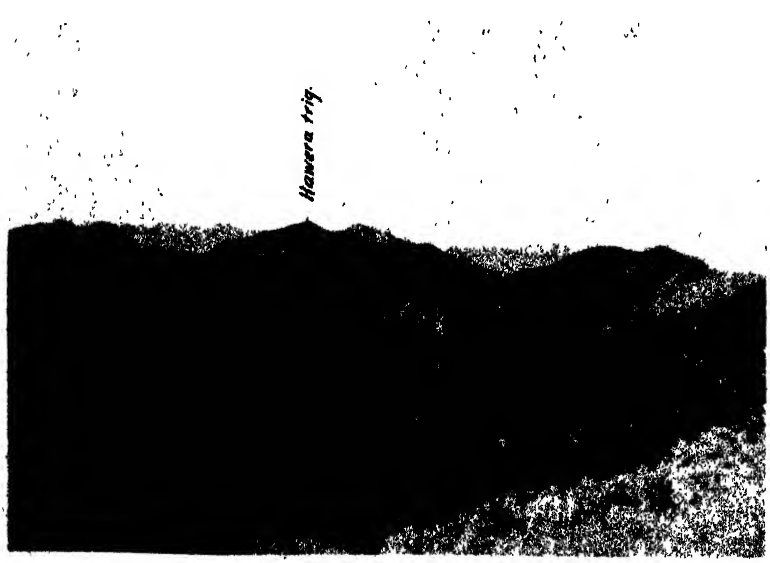

FIG. 2.—Pike River Coalfield looking north from trig. C, 2 miles west of Mt. Anderson. (Photo. by G. G. Cossens)

OUTLINE OF GEOLOGY

The geology of the district is illustrated by a sketch map and a cross-section (Fig. 1). The economically important part is a gently east-dipping block capped by thick Island sandstone which extends for more than a mile south-east of trig. Q.

The Island sandstone area shows distinctive vegetation and topography. Although only 3,000 ft. above sea-level and 500 ft. below the normal bush line, it is covered only by sub-alpine scrub and tussock. The surface is comparatively flat and the attidude of the underlying rock is clearly shown by the surface slopes. The outcrop of the Island sandstone block forms a high west-facing escarpment which extends almost without interruption from a mile north of Mt. Anderson to the head of Tindale Creek (See Fig. 2). Over most of this distance the escarpment is unscaleable, the only known routes being down a narrow cleft about half a mile south-west of trig. Q and along the ridge between Tindale Creek and the most northerly branch of Punakaiki River.

The eastern boundary of Island sandstone is a major fault named Hawera Fault, upthrown to the east, which passes a few chains east of trig. Q and extends for an unknown distance to the north and south.

The coal measures below the Island sandstone were examined only in the valley of Tindale Creek. Below the Island sandstone, and separated from it by a few feet only of quartz sands, is a seam of clean bituminous coal at least 12 ft. thick. The outcrop is in about the same place as coal marked "coal seam reported" on Henderson's map.

LATER INVESTIGATIONS

Early in 1947 the southern part of the coalfield was visited by Greymouth members of the Geological Survey and an unpublished account written by Mr. G. W. Patterson. The old formed track was followed from Atarau to an old hut near the headwaters of Moonlight Creek. A stiff climb through thick scrub separated this hut from the main divide of the range which was followed past Mt. Anderson to the south end of the coalfield where a camp was established. The total time taken from the end of the road, 11 hours, was about the same as by the more direct route up the valley of Pike River. Rain made it impossible for the party to do more than examine the south end of the coalfield where a complete section was measured through the coal measures.

STRATIGRAPHY

The following formations are exposed at and near the coalfield.

	Feet.
Tertiary:	
Cobden limestone	700
Kaiata mudstone	500
Island sandstone	50–1000
Brunner Beds	50
Cretaceous:	
Paparoa Beds	2000
Hawk's Crag Breccia	0–5000

REGIONAL UNCONFORMITY

Palaeozoic Undermass:—
Granite and gneiss
Greywacke, argillite and hornfels.

UNDERMASS

Gneissic granite forms the lower part of Pike River gorge, and is shown by Henderson as widening to the north and extending across the whole width of the Paparoa Range. West of the divide granite was seen only in the middle reaches of Tindale Creek about two miles from its junction with Porarari River. The granite shows complex but well exposed contacts. The greywacke to the west is changed to a dark glassy hornfels ; and it is probable that granite extends west at no great depth. The greywacke to the east is brecciated but not contact-metamorphosed, and for this reason the eastern greywacke-granite contact has been shown as a fault on the map.

HAWK'S CRAG BRECCIA

Hawk's Crag Breccia is well exposed for three miles in the lower and middle reaches of Pike River. For this whole distance the breccia is relatively uniform, a representative outcrop showing moderately well compacted sub-rounded to sub-angular fragments of greywacke and granite up to 6 in. The average size of the fragments is about 1 in. and about 75 per cent. are greywacke. The proportion of granite (including gneiss) to greywacke is far less in the Hawk's Crag Breccia, than in the gravels of Pike River and granite appears to have been less exposed in Hawk's Crag times than now.

Boulders of conglomerate containing pebbles of basalt are not uncommon on both sides of the range. Similar conglomerate forms part of the Morgan formation of the Paparoa beds in the Greymouth district and it is probable that the Morgan formation extends north to the area under discussion.

It is not improbable that some of the finer conglomerates mapped as Hawk's Crag Breccia are the time equivalents of sandstones and conglomerates mapped as Paparoa beds at Greymouth, and a true correlation could perhaps be effected by detailed mapping of the basalt bearing conglomerates that are known to be confined to a single horizon a few hundred feet above the top of the Hawk's Crag Breccia in the Greymouth coalfield.

PAPAROA BEDS

Paparoa beds are exposed on both sides of the Hawera Fault. To the east of the fault on the upthrown side they form the top of Hawera Hill (trig. Q) and extend for an unknown distance to the north. To the west of the fault they are well developed at the head of Tindale Creek and probably extend south below the Island sandstone escarpment almost to Mt. Anderson. The following section was measured just east of Hawera Hill :—

	Feet
Conglomerate, 2in. greywacke and granite	2
Alternating sandstone and shale	100
Sandstone and conglomerate	3
Soft shale with minor sandstones	50
Alternating sandstone and shale	80
Sandstone and greywacke conglomerate	30
Greywacke basement	

The dip of the section is not regular throughout ; at the top it is 20° south-east and at the bottom 45° north-east ; small faults are common and no coal was seen. Although many good sections through the Paparoa Beds must be exposed in the steep hillside below the Island sandstone escarpment, the section examined, on the south side of the headwaters of Tindale Creek, showed only the upper and lower parts, the middle part being largely covered by huge blocks of Island sandstone. The lower part is separated from the greywacke undermass by Hawk's Crag Breccia not more than 300 ft. thick and is similar to the section already described east of Hawera Fault. The middle part contains golden-yellow arkositic sandstones and can probably be correlated with the Rewanui formation of Greymouth. The upper 100 ft. is well exposed and shows predominately light coloured mudstones with minor sandstone bands and is similar to the Dunollie formation of Greymouth. No coal seams were seen in the Paparoa beds, but the section examined was so poorly exposed that even thick seams could well have been missed.

Patterson measured the following section at the south end of the coalfield :-

	Feet
Alternating 3 ft. bands of mudstone and yellow arkositic sandstone with ironstone concretions	200
Mudstone with small sandstone bands and ironstone concretions	100
COAL (Thickens to 7 ft. 2 chains north)	2
Alternating sandstone and mudstone	100
COAL (thickens to 20 ft. to north)	12
Alternating sandstone and mudstone	50
COAL	4
Sandstone with minor mudstone	100
COAL	8
Coarse sandstone	50
Conglomerate of greywacke and quartz, 2 in., sub-rounded	50
Unconformity : Undermass, greywacke.	

BRUNNER BEDS

Brunner beds were seen only on the ridge between the headwaters of the Porarari and Punakaiki rivers, where they are no more than 50 ft. thick and are represented by bands of quartz sandstone and fireclays below the coal, a coal seam at least 12 ft. thick, and thin quartz sandstone between the coal and the overlying Island sandstone. The following section was measured by Patterson at the south end of the coalfield :—

	Feet
Slightly calcareous medium sandstone (Island Sandstone)	200 +
Sandstone	5
COAL with sandstone bands	3
Sandstone	4
COAL with sandstone bands	7
Sandstone	2
COAL	4
Quartz sandstone	30

Patterson also reports 25 ft. of clean coal in Brunner beds half a mile north of his measured section.

ISLAND SANDSTONE

The Island sandstone is the most conspicuous formation in the coalfield, and is well exposed in both the escarpment and the back slope of the block. The formation is at least 1000 ft. thick and remarkably uniform throughout, consisting of slightly calcareous medium brown muddy fine sandstone, with borings and scattered fossils. The following poorly preserved fossil casts identified by Dr. J. Marwick are from a sample of weathered sandstone from the upper part of the Island sandstone.

S.37/577 = G.S. 3608, Paparoa Range near bush line, vicinity of Trig. Q, Waiwhero S.D. Island sandstone or Kaiatan.

Lentipecten parki Marw.
Laevidentalium sp.
? *Notocyathus* sp.

The smooth surface of the back slope of the escarpment is due to the overlying softer Kaiata mudstone having been stripped from it.

KAIATA MUDSTONE

Within the coalfield Kaiata mudstone was seen only at one place in the extreme corner of the Hawera fault-angle depression where it is protected from erosion by resistant upfaulted greywacke to the east. It is a moderately hard dark brown-grey slightly calcereous muddy siltstone similar to the Kaiata mudstone of the type locality in the Greymouth district, and harder but otherwise similar to mudstone of the same age on both flanks of the range.

CORRELATION AND RANK OF COAL SEAM

The coal seam, lying just below the base of the Island sandstone, can be correlated with a coal seam in the same stratigraphic position in other parts of Westland. The nearest of these is to the west where coal immediately below Island sandstone is known to extend north-east from the head of Lawson (Waiwhero) Creek to Porarari River, (Gage and Wellman, 1944, p. 119). This seam is 20 ft. thick at Lawson (Waiwhero) Creek but thins to 3 ft. at the Porarari River. It is directly overlain by Island sandstone and rests directly on the greywacke undermass. Coal of the same age occurs 6 miles to the south at Garden Gully and Fitzgerald Creek, two small tributaries of Moonlight Creek. At both these places a 20 ft. seam is directly overlain by Island sandstone and rests directly on greywacke basement. Thick coal in a similar stratigraphic position is well exposed in Smoke-ho Creek near Blackball 10 miles south-east. Although these seams have the same stratigraphic position and must be of the same age the following table shows that they vary considerably in rank.

	Formation.	M.	V.M.	F.C.	Ash	S.	Rank.
(1) Garden Gully	Brunner	17.5	46.5	34.9	1.1	4.3	8.0
(2) Smoke-ho Creek	Brunner	4.9	45.7	47.1	2.3	4.8	14.5
(3) Lawson Creek	Brunner	13.5	39.5	40.2	6.8	n.d.	9.8
(4) Punakaiki River	Brunner	10.5	41.0	39.0	9.5	3.5	10.6
(5) Pike River coalfield		8.0	37.2	54.0	0.8	1.6	20–22*
(6) Pike River south end	Paparoa	1.7	31.3	65.2	1.8	n.d.	20–22*
(7) Coal pebble Punakaiki River		9.2	35.2	45.4	10.2	0.7	12.2

* Weathered coal, coal assumed to be of same type as Brunner coal at Brunner, and rank determined indirectly.

The coal rank classification used above is described fully in (*N.Z. Geol. Surv. Bulletin* 45,) "The Geology of the Greymouth Coalfield" (now in the press). The rank of the coal increases with increasing thickness of the Island sandstone. The seams near the crest of the range (2, 4, and 5) are above rank 14 and are bituminous, whereas further from the crest (1 and 3) the seams are sub-bituminous.

EVOLUTION OF PIKE RIVER COALFIELD

Although the Pike River coalfield is now an isolated outlier on the crest of the Paparoa Range it once formed part of an extensive sheet of sediments that extended west to Lawson Creek, south to the Greymouth coalfield and east to Garden Gully and Fitzgerald Creek. Its present isolation is due to erosion, erosion that took place during at least two distinct periods in the past. Cotton, from a study of north-west Nelson peneplains, was the first to show that the Tertiary covering strata had been deposited over a much greater area than they now occupy and that erosion had stripped the once continuous cover from many of elevated areas. This is now generally accepted. At Pike River coalfield the argument can be taken a stage further, for not only did the early Tertiary sediments necessarily extend over the Paparoa range, but the sediments eroded from near the crest were thicker than those still preserved on the less elevated flanks of the range.

It will be shown later that the Paparoa Range is a tectonic unit and has behaved as a tectonic unit in the past, both elevations and depressions in different parts being primarily related to distance from a central axis. Having sections exposed at the axis and on both flanks, it is possible to reconstruct something of its evolutionary history. Four stages have been illustrated by cross sections along a line normal to the Paparoa Range through the coalfield. The representation of the undermass, which is shown in each to indicate that it must have been deformed together with the covering beds, is (except for granite-greywacke contacts) purely diagrammatic. On the east of the range, information is not available on the line of section itself, but has been projected on to it from Garden Gully, Fitzgerald Creek, and Blackball, points respectively 4, 5, and 9 miles to the south. The first stage (Fig. 3A) represents conditions after the deposition of the Hawk's Crag Breccia, Paparoa beds, and Island sandstone but before the deposition of the Kaiata mudstone. The Hawk's Crag Breccia is known to be a fanglomerate deposited close to its place of origin, very variable in thickness, and probably filling a narrow depression in the undermass. It does not occur at Garden Gully or at Hawera Trig. and could not have extended there in Island sandstone times. The Paparoa beds are more extensive but did not extend to either Lawson Creek or Garden Gully where Brunner beds rest directly on the undermass. In contrast to these two formations the Brunner beds are thin but more uniform in thickness and must have been deposited on a surface that extended evenly over undermass, Hawk's Crag Breccia, and Paparoa beds alike. This even surface provides the best reference by which to measure later depressions and elevations. The fine even-grained Island sandstone shows no significant variations in lithology where now preserved along the line of section and it is reasonable on lithologic grounds to suppose that it once extended as a continuous sheet over what is now the southern end of the Paparoa Range. The thickness of the Island sandstone, where still preserved, shows that not only was the Paparoa undermass covered but that the thickness of the

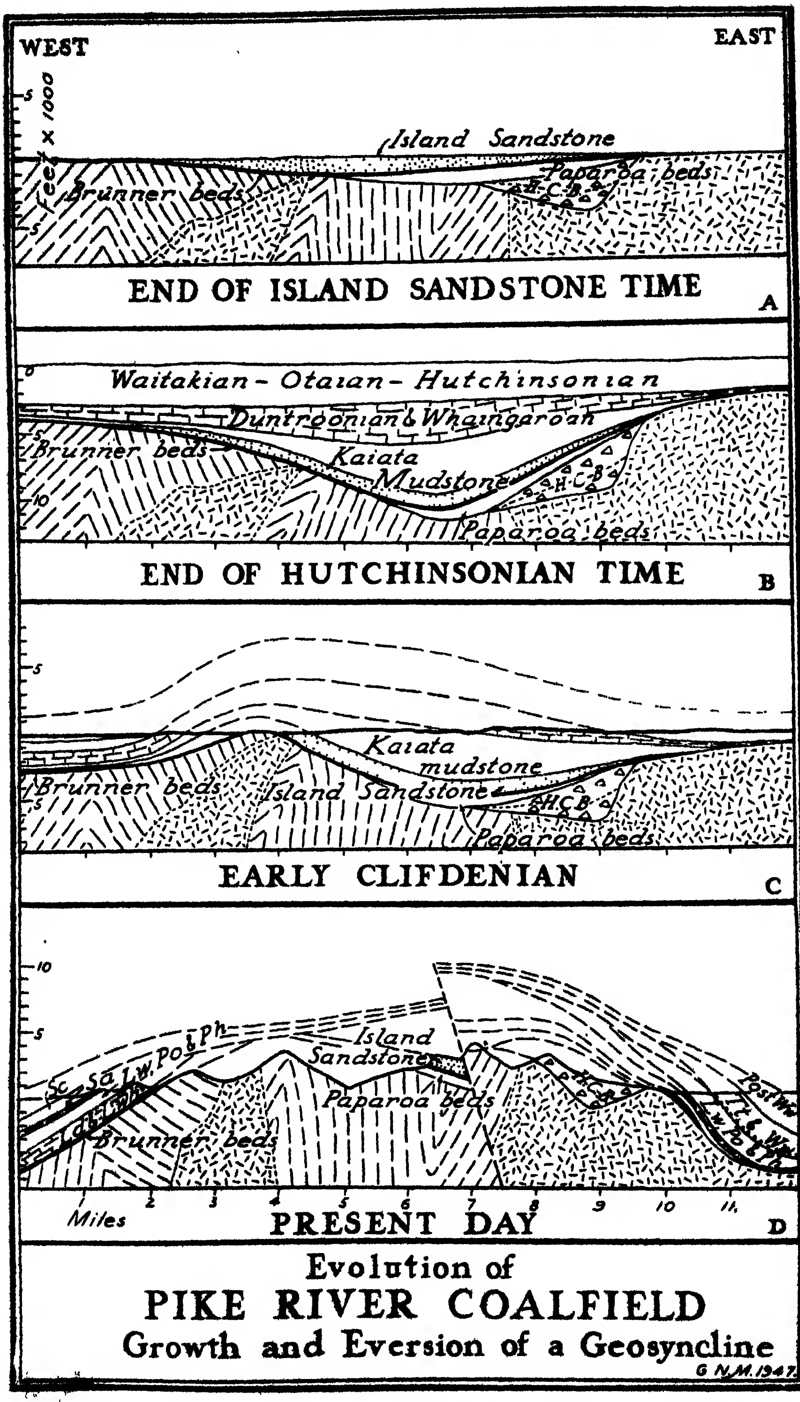

FIG. 3.—Diagrammatic cross sections along the same line of section as Fig. 1, showing the growth of the geosyncline and the formation of the Paparoa anticlinal range. The vertical and horizontal scales of these cross sections are equal.

sandstone increased towards what is now the crest of the range, for the exposed thicknesses increase from about 200 ft. at Lawson Creek to nearly 1000 ft. at Porarari River reaching over 1000 ft. at the crest of the Range, and then decreasing on the east side to 500 ft. at Blackball, 100 ft. at Garden Gully, and completely disappearing before the Notown Bore, 7 miles from the crest, is reached. The variations in the thickness of the sandstone are so regular and agree so closely with the rank of coal that there is little difficulty in filling in the gaps and completing the cross section Fig. 3A.

The next stage, that of maximum subsidence, is more hypothetical and depends in large part on depth of maximum burial deduced from coal rank. Study of Greymouth coal analyses showed a relation between analyses and depth of burial, this relation being obtained from bore holes and surface sections independent of stratigraphy, the method used being described in full in Chapter 12 of *N.Z. Geol. Surv. Bull. 45* (now in press). The numerical values given for rank are proportional to total depths of burial, each unit rank representing 500 ft. increase in depth of burial. The coal analyses considered are all from the Brunner beds and the appropriate depth for each sample is shown by Fig. 3B. The coal rank decreases away from the crest of the range and the maximum depths of burial consequently decrease accordingly, the Brunner beds being warped into a geosynclinal trough. The thickness of Hawk's Crag Breccia, Paparoa beds, Brunner beds, and Island sandstone have been transferred from Fig. 3A. It will be noted that the Island sandstone thicknesses increase with increasing depth of the trough so as to partly fill the depression in proportion to its depth. The Island sandstone is known to be overlain by Kaiatan mudstone and by Cobden limestone of Whaingaroan and Duntroonian age on both flanks of the range and it is reasonable to consider that these beds also once extended across this area. Sections through these two formations are exposed at Lawson Creek, Porarari River, and the measured thicknesses have been transferred to this cross section. As with the Island sandstone the sections closest to the axis of the range show the greatest thicknesses. From this evidence it is possible to reconstruct the thickness of the beds filling the geosyncline up to the end of Duntroonian times. It will be seen that about 3000 ft. remains to be infilled, the time available being limited by the onset of the pre-Altonian orogeny. This orogeny is well marked over the whole of the West Coast where at least the Awamoan stage is missing from all sections so far examined, the position of the missing stage or stages being marked by well defined evidence for erosion. The three stages, Waitakian, Otaian, and Hutchinsonian represent the time interval between the Duntroonian and the orogeny. At Porarari River Waitakian and Otaian are both represented by about 1000 ft. of beds and the Hutchinsonian, although eroded from this section, is represented to the north near Fox River by 500 ft. of fine grained beds. On the east side of the range at Fitzgerald Creek only Otaian beds of unknown thickness are known. These beds are all either fine sandstones or mudstones and show no evidence of a nearby shore line, and it is reasonable to consider that they also extended across to complete the infilling of the geosyncline. The stratigraphic evidence is not sufficient to check fully the evidence given by coal ranks, but does not clash with it.

By considering the thickness represented by each Tertiary stage it will be noticed that the rate of subsidence increased to a maximum in Kaiatan times and then decreased. The rate of subsidence was slow

but uniform in Brunner times, less slow and uniform in Bortonian times (lower Island sandstone) rapid and variable in Kaiatan times (upper Island sandstone and Kaiata mudstone) and then less rapid and more regular in the following stages preceding the orogeny.

The next stage in the evolutionary sequence is the most difficult to reconstruct. At almost all places on the West Coast of the South Island the Southland Series (Finlay and Marwick, 1947) is known to have followed an orogenic period and to rest unconformably on older beds. At Fox River (Wellman, 1946, p. 228) the older Tertiary beds had been faulted and folded before this series was deposited but at most places the break is not conspicuous and our knowledge of the shore line is slight. However more is known along the line of section where coal rank again provides a clue (already remarked upon by Henderson, 1917, p. 70). Coal pebbles are conspicuous in limestone (mapped as middle Miocene by Henderson but now known to be Altonian) near the mouth of Punakaiki River at the west end of the line of section. An analysis of one of these pebbles is given by Henderson and is included in the table of analyses (No. 7). Henderson suggested that this pebble came from near the Lawson Creek coal outcrop. The analysis shows that it is of higher rank than the Lawson Creek coal, and, as we know something of the rate at which the coal rank could be expected to increase towards the axis of the range, it is easy to find an appropriate origin for the pebble. This proves to be about a mile east of the Lawson Creek outcrop and is consistent with a reasonable angle of overlap. The Altonian overlap could not have extended down to the Brunner Beds or the undermass further to the east on the west side of the range for both coal measures, Island Sandstone, and fragments of Kaiatan Beds are still preserved there. Moreover Altonian and Clifdenian beds on the east of the range show no coal pebbles and there is consequently no reason to suppose that the overlap extended down to the undermass on any part of that side. Still further east at Fitzgerald Creek the Lower Tertiary sequence is known to extend up to the Otaian and this sets a downward limit for the Altonian overlap there. This evidence is sufficient to provide information for Fig. 3C. It will be noted that the geosyncline that had subsided so regularly was bulged up on its western flank and that over a mile of the lower Tertiary sediments must have been stripped off during Awamoan time along this anticlinal axis. This same uplift extended many miles north, for an overlap of soft Waiuan beds on hard Island Sandstone and coal measures with bituminous coal and semi-anthracite is known from upper Fox River (Wellman, 1946) and upper Tertiary beds (Waiuan) have been reported by Morgan (1915, opp. p. 198) resting on Kaiata mudstone near Waimangaroa. This second period of marine deposition came to an end after the Waitotaran when the sea retreated and non-marine beds were deposited. The Kaikoura Orogeny followed and the land was again elevated, the softer and higher Tertiary beds eroded, and the land approached its present form (Fig. 3D). During this orogeny the east side of the old geosyncline was elevated and faulted so as to produce a mountain range out of what was once a Tertiary-filled geosyncline. It will be noted that the present elevation of the range bears a rough relation to the original amount of depression, the elevation being about a quarter that of the depression. Normally such elevation would be followed by erosion and all record of the original thick sediments destroyed; but by a fortunate geological accident the Kaiata mudstone and the thick Island sandstone have been protected from erosion in the fault angle of the Hawera fault. Since the geosynclinal phase the

Paparoa Range has been turned inside out, the deeper parts of the geosyncline now forming the crest of the range, while the margins of the geosyncline form the margin of the range. This major reversal can be conveniently termed eversion.

It is a common occurrence for mountains to be formed from geosynclines, but the Paparoa Range differs from most of the classical geosynclinal mountains in that its width is only 12 miles, while the total time of development was shorter, both geosynclinal sinking and orogenic uplift being confined to the Tertiary epoch.

RECOMMENDATIONS FOR FUTURE WORK

The Pike River coalfield is a bituminous coal-bearing area of some importance; the Island sandstone covers an area of about 1½ square miles, the dip is low, and the area is unlikely to be severely faulted. Before any important tonnage of coal can be considered "proved" the coal seam will have to be traced south along the foot of the escarpment. Access will not be easy for the prospecting party, but the work could probably be more easily done from the east than from the west side of the Paparoa Range.

The later work done by Patterson has shown that the Brunner seam persists to the south end of the coalfield, and it is reasonable to expect that it will contain some 15 million tons of coal. The Paparoa seams reported by Patterson have been traced only a few chains, but it is likely that they will contain an equal amount of coal. All samples so far analysed are weathered and contain more moisture than the coal in from the outcrop. However it can be inferred with certainty that the coal will be bituminous, that in the Brunner Beds being similar to Wallsend coal and that in the Paparoa beds similar to Liverpool coal.

Although the coalfield is on the crest of the Paparoa Range access to the coal, although difficult, is not impracticable from the east. The Brunner seam, about 2,000-2,500 ft. on the west side of the coalfield, dips east and will probably be no more than 1,000-1,500 ft. at the fault angle on the eastern side where the seam could be reached by a drive about a mile long driven from a point in the valley of Pike River 1,000 ft. above sea-level. Seven miles of road would have to be constructed to connect the mouth of the drive to the present end of the formed road. Road construction for the lower 4 miles would be across alluvial terraces and would be easy, but the upper 3 miles would be more difficult becoming progressively more so in the upper part of the River.

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THE ORIGIN OF SALT PANS IN CENTRAL OTAGO

By J. D. RAESIDE, Soil Bureau, Department of Scientific and Industrial Research

Summary

Evidence is presented explaining the salt pans of Central Otago as having been formed by deflation where vegetation has been killed out by high concentrations of soluble salts.

Profiles of some of the pans show solonetz structures.

PANS, or shallow saucer-shaped depressions, are common features of the Central Otago intermontane basins. They occur mostly on flat or gently undulating land surfaces where only a thin veneer of alluvium rests on salt-bearing Tertiary sediments, or where these sediments outcrop on the surface. They develop more rarely on rolling land surfaces.

The pans are roughly circular to oval depressions (Figs. 1 and 2), flat floored, from 3 to 30 yd. across (average 8 yd.), and from 1 to 6 ft. deep (average 4 ft.). The floor is mostly compact and cemented and ranges in texture from a heavy silt loam to a clay loam. In some pans it is covered with a layer of stones and in others with a layer of mixed clay and stones.

On some sloping land surfaces the pans show a conspicuous linear arrangement and appear to follow the lines of outcrop of horizontal Tertiary beds (Fig. 1), mostly sandstones with bands of impermeable gypseous and salt bearing clays. Some pans are congregated on terraces where the salt bearing clays lie close to the surface. There is a close relationship between the thickness of the veneer of alluvium and the development of the pans. Where the alluvial cover on the surface of the Tertiary sediments is 3 ft. thick or less, pans are abundant (Fig. 2).

Some 91 pans were counted within an area of 120 acres situated on a terrace composed of Tertiary silts and clays and covered with a discontinuous veneer of alluvium less than 2 ft. thick, some 2 miles south of Gimmerburn. Where the alluvial cover is thicker than 2 ft., pans are less abundant, and where it exceeds 5 ft. in thickness they do not commonly occur.

The floors of the pans appear to correspond mostly with the level of the surface of the Tertiary sediments, particularly where the sediments are impermeable. Where the uppermost sediments are coarse, the pans are commonly excavated somewhat deeper. The floors of many pans appear also to be supplied with water from perched water tables. It is possible that the floor of the pan stands at about the level of the perched acquifer. In the Stony Creek neighbourhood when water is diverted from the upper reaches of the stream to irrigate fields lying to the south of it, pans scattered over adjacent fields, and previously dry, now fill with water, and others, flanking the stream, dry out almost entirely. The dampness of many other pans, where no irrigation has taken place, may indicate that these also receive water from perched water tables. Unless irrigation has augmented the ground waters, only a small amount of seepage water can perch on the impermeable beds which in places would appear to form the floors of these pans. The seepage water is mainly saline and contains the sulphates, chlorides and carbonates of calcium, magnesium and sodium.

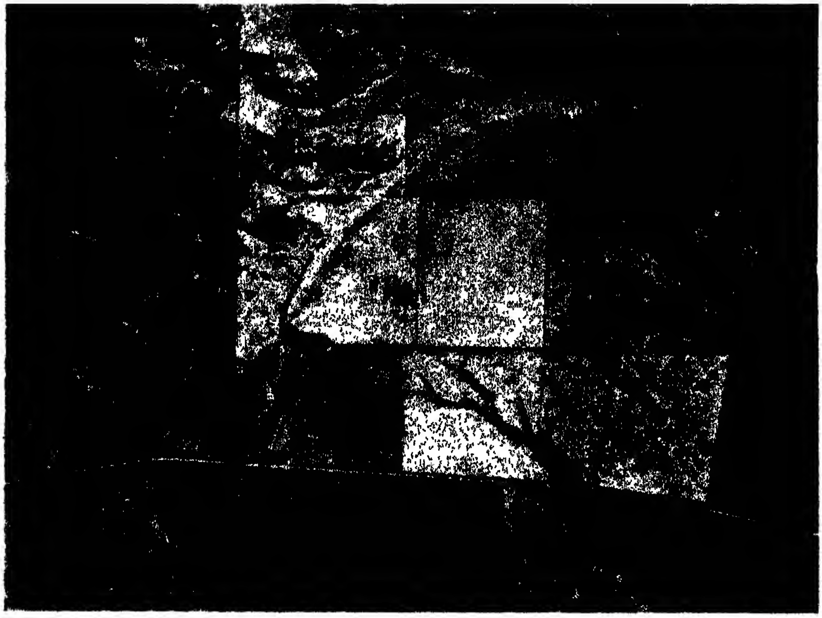

FIG. 1.—Aerial photograph showing a number of pans on a terrace composed of Tertiary beds thinly veneered with alluvium. On the higher and better drained part of the terrace there are no pans.

The pans were first described by Park (1905). In discussing the lands forms of the Alexandra district, he classified them as sink holes, but did not suggest how they might have been formed. He described them only in general terms and noted that they were associated with Tertiary clays which were covered with a thin skin of recent gravels.

Ferrar (1929), appeared to accept Park's view. He considered that some of the pans were formed by the removal of material through downward drainage into underlying gravel beds, or into underlying Tertiary sediments by way of joints. He likened these to limestone sink holes. Others he regarded as watercourse meanders formed by the migration of the streams that formed them, and cited the meanders of the Taieri River as examples.

To avoid confusion, it may be best to confine the use of the term "pan" to the shallow basins distributed indiscriminately over uplands as well as valley floors and clearly removed from natural drainage channels. Hollows in deserted meanders are thus better excluded. They have totally different characteristics. Although they may be well defined, the ancient meanders on which they lie strongly point to an origin through the normal local overdeepening or scouring of stream channels (Fig. 3).

Other structures classed by Ferrar as pans are better regarded as ponds, e.g., a typical example of this type of pan has been formed by

the intersection of two "banners" of wind-borne material near Patearoa. In the case of another pan of this type occupying a crateriform hollow in the schist, Ferrar actually qualifies his description by adding that it is a true rock basin formed by differential decomposition of the schist.

The suggestions advanced hitherto to explain the origin of the pans are not altogether satisfactory. Although Park classified them as sink holes, he advanced no reasons for this view. The common mechanism of formation of sink holes is by the solution of limestones; but no limestones underlie any of the pans examined in Central Otago, nor are there any recorded among the sediments of the districts where the pans occur.

Ferrar's explanation that the pans are formed through removal of material by downward drainage into underlying gravel beds, a development of the sink hole hypothesis, is equally unacceptable, for the pans are nowhere underlain by gravels. On thick deposits of gravels pans do not form. The thin veneer of alluvium on surfaces where the pans are most plentiful is underlain by relatively impermeable Tertiary sediments. Ferrar's further assertion that the material may be removed by downward drainage through cracks into the underlying Tertiary beds is also irreconcilable with the structure of the pans. The cracks which appear in summer are shallow, and do not extend downward more than a few inches from the surface. The draining of the material into the cracks would involve merely a reshuffle of the surface.

FIG. 2.—Pans formed on a wide valley floor about 2 miles west of Ranfurly. The floor consists of heavy sediments covered with a thin veneer of alluvium.

FIG. 3.—Valley of Wetherburn stream about 5 miles from Gimmerburn showing deserted meanders. A few isolated hollows mark the course of the deserted meander in the foreground.

It seems indisputable that the hollows must be destructional land forms (a constructional origin would require the surrounding land to be raised), and an origin through subsidence cannot be maintained. A destructional origin requires the agency of either water or wind. Water may be dismissed as a possible agent, for the pans show no connection whatever with lines of natural surface drainage, and develop as well on ridge tops and uplands as on valley floors. Excavation by wind, however, involves no difficulties, and it is therefore suggested that they may be satisfactorily explained by deflation.

The following tentative theory is suggested to explain the origin of the pans. The Tertiary sediments on which the pans form are horizontally bedded, salt bearing, and contain many impermeable bands of clays and fine silts on which ground waters perch. The salt content of ground waters is thus steadily augmented as it percolates downwards through the salt bearing sediments. These saline ground waters are held by the first impermeable band in their path, and may be fed to the surface where the impermeable band outcrops, there to appear as springs or seepages. If pans perch at shallow depths the water level may recede below the surface during the summer drought, and in this way soluble salts begin to accumulate in the topsoil and subsoil, and sometimes also on the surface on the ground. In time the vegetation is killed out over a small area. Where sodium salts are present, sodium clays are formed and in summer the soil cracks extensively. At the same time the surface exfoliates (Fig. 4), the exfoliated crust blows away, and the level of the surface is slightly reduced. The process may be an annual one or it may depend on a suitable sequence of seasons to bring the salt to the surface

FIG. 4.—Floor of a pan in the Gimmerburn district showing exfoliation of a thin crust of the surface, and doming of the tops of hexagonal structures.

and there evaporate it. The nett result of several repetitions of the process, however, is that a small depression gradually forms. The rate at which the floor deepens depends largely on such factors as the degree of salinity of the perched ground water, the nature of the salts it contains, and the duration of its impress on the soil. But given a permanent source of salt, as the excavation proceeds the floor of the hollow approaches nearer to the source of the salt, and there is less and less chance of vegetation covering the affected spot and halting the process.

The average depth of 3 to 4 ft. indicates that at this level the pans become stabilised, and the deflation is reduced to negligible proportions. It is possible that this may be due to one or more of the following factors:—

1. The eroding floor of the pan may be reduced far enough to reach the heavy Tertiary sediments on which the ground waters are perched. If there is a constant supply of water the floor will remain damp for most of the year, and deflation will be arrested. Many pans of this type have been observed.

2. Stones and gravels derived from the alluvial veneer through which the hollow was excavated may accumulate sufficiently to protect the floor from further deflation. Pans stabilised in this way are common on higher terraces where they have been excavated through a thin veneer of ancient stony greywacke alluvium. Park (1905) recorded pans whose floors were "lined with a layer of yellow cement-stone", probably remnants of disintegrated "Sarsen" stones.

3. When a depth of 3 to 4 ft. has been reached the transporting power of the wind may be reduced to small proportions, and any loss of material from the floor may be balanced by the addition of drifting sand and silt which accumulate in the pans.

It is possible that many of the hollows in dried stream beds may have been deepened by the same process as that which formed the pans, for many valley floors are slightly saline. However, as the process has been initiated by stream action the extent to which the water scoured holes in the stream bed have been further deepened by deflation is not easily estimated.

Many pans possess structures closely resembling those characteristic of solonetz soils. On drying, the floors of the pans shrink and a network of cracks develops, breaking the surface into a mosaic of rude hexagons ranging from 4 to 9 in. in diameter. In many pans, especially some of the shallower ones, the rude hexagons show a well marked doming. In some a layer of fine silica sand covers the floor to a depth of ¼ to ½ in., but under this the clay loams show the same doming. It is possible that these pans represent an early stage in the solonetz process.

The domed structure of the solonetz subsoils is thought to be caused by the alternate swelling and shrinking of clays partly saturated with sodium salts. The summer shrinkage produces the characteristic pattern of cracks in which material from the sides of the cracks and from the surface of the ground may accumulate. The material lodged in the cracks prevents them from closing when the soil wets and swells in winter. The extra volume of the swelled soil, however, still has to be accommodated, and accordingly the surface of each hexagonal pillar bulges upwards. The process is intermittent and the various stages show clearly as a series of steps on each dome. (Fig. 4.) The material which fills the cracks is supplied in a haphazard manner and not every crack is filled to the same degree. Consequently, the doming does not follow a regular pattern; some hexagons show conspicuous doming while others show little or none.

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EARTHQUAKES IN NEW ZEALAND DURING THE YEAR 1947

By R. C. HAYES, Dominion Observatory, Scientific and Industrial Research Department, Wellington

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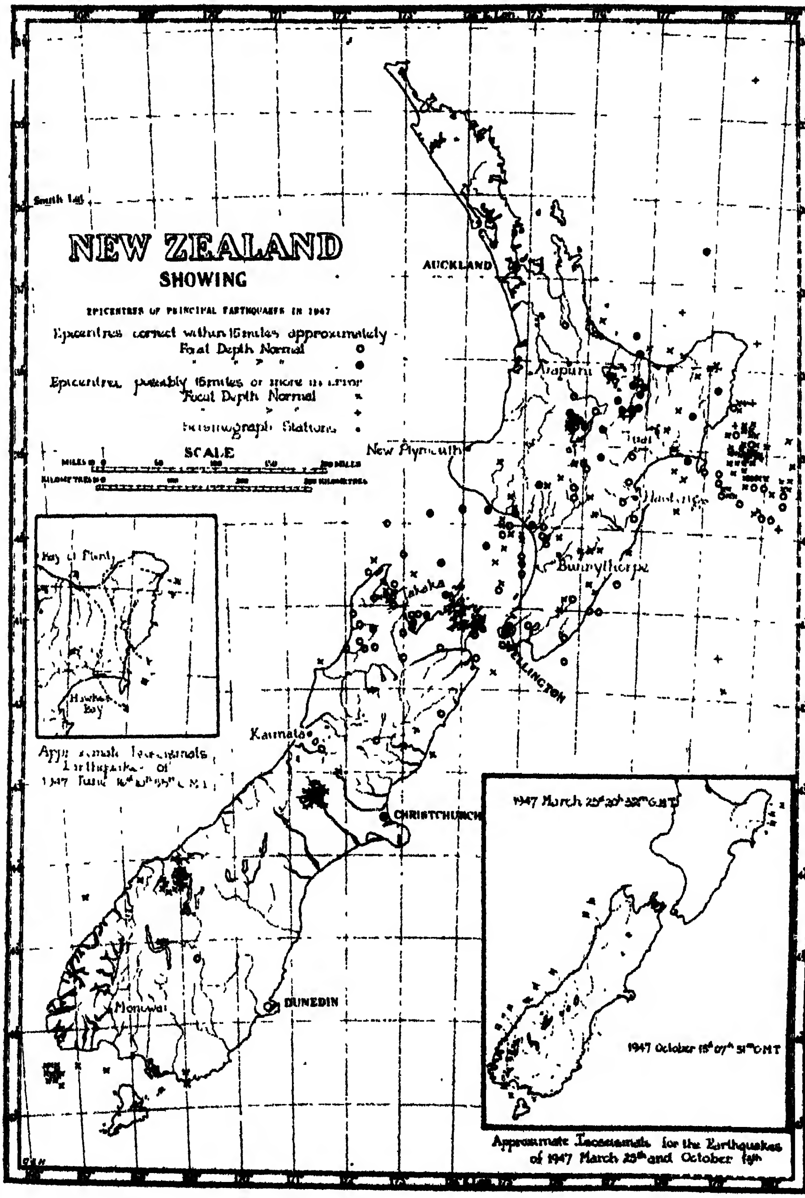
PARTICULARS of all earthquakes in the New Zealand region during the year 1947, whose epicentres were determined, are tabulated below. The epicentres of these earthquakes are shown on the accompanying map, except in the case of seven shocks, which originated outside the boundary of the map. Distinctive symbols are used to denote accuracy of epicentre and depths greater than normal. The approximate isoseismals for three of the most important earthquakes are shown on inset maps.

Origin Time (G.M.T.)* 1947	Origin Time (G.M.T.)* h. m.	Epicentre Lat.S (deg.)	Epicentre Long.E (deg.)	Max. Felt Intensity (M-M)
Jan.				
3	02 25.2	41.6	173.0	
5	03 58.4	40.5	172.5	-
5	10 40ca	43.2	171.4	II
10	05 05.1	38.2	176.8	-
10	16 08.8	46.5	164.0	IV
15	10 35.0	40.4	173.0	
16	14 41ca	46.5	168.4	II
17	22 11.9	43.2	171.4	IV
19	19 22.5	41.1	173.1	III
19	19 35.5	44.4	167.2	III
20	07 04.7	37.7	176.8	
20	18 34ca	43.2	171.4	III
20	22 08.9	38.2	178.1	-
22	20 23.2	41.3	173.0	IV
24	23 54.7	38.3	176.9	-
27	13 03.2	39.5	175.4	IV
27	21 40.4	38.4	176.5	
28	23 13.5	42.5	173.2	-
30	08 44.2	39.4	175.6	-
Feb.				
1	08 45.0	41.5	178.4	—
4	21 06.4	43.2	171.4	V
4	21 14ca	43.2	171.4	II
4	21 14.6	43.2	171.4	II
5	20 58.0	38.8	176.0	—
7	21 15ca	43.2	171.4	III
8	18 45.0	43.2	171.4	V
9	04 19.0	43.0	171.9	III
9	12 55ca	43.2	171.4	II
9	15 55ca	43.2	171.4	IV
10	19 25.5	41.5	172.2	III
11	07 04.3	39.2	176.0	—
15	03 09.5	40.7	176.1	—
16	15 30.3	40.9	173.8	V
16	22 03.3	41.2	174.8	III
17	09 48.9	38.1	176.4	IV
23	10 42.6	40.1	174.7	IV
Mar				
3	20 51.4	39.7	174.8	
6	13 08.9	38.5	176.5	-
6	15 48.7	39.2	175.9	
13	22 03.2	40.9	175.9	II
14	10 18.2	40.6	175.0	II
15	01 24.5	40.0	174.7	III
16	14 52.0	40.0	174.7	IV
22	19 90 6	39.6	176.7	IV
25	20 32.2	38.8	178.5	IV
25	22 15ca	38.0	177.3	I
26	07 18.1	40.1	175.0	III
26	09 08.2	42.7	171.6	III
26	16 09ca	45.0	168.7	III
27	18 25.4	39.2	178.2	V
29	23 47.8	39.1	178.4	III
30	02 53.6	39.3	178.2	III
Apr.				
2	14 44.4	37.5	176.2	-
2	21 45.7	39.4	178.4	III
3	21 10.9	39.6	178.6	III
4	01 38.7	39.5	178.4	II
4	12 28.7	39.4	178.3	II
7	09 45.0	39.5	178.3	III
8	09 30.7	37.8	177.3	II
10	17 40.7	39.5	178.5	II
16	07 10.9	38.7	175.8	III
16	07 31.8	38.7	175.8	II
16	08 04.9	38.7	175.8	III
16	09 39ca	39.7	175.8	III
16	12 42.0	38.7	175.8	III
16	13 30ca	38.7	175.8	IV
16	13 45ca	38.7	175.8	III
16	14 47.2	38.7	175.8	IV
16	20 59.8	38.7	180.0	—
17	01 27.5	39.2	178.0	IV
17	04 16.4	39.8	174.9	—
19	20 08.5	37.4	175.5	IV

Origin Time (G.M.T.)* 1947	h. m.	Epicentre: Lat.S (deg.)	Long.E (deg.)	Max. Felt Intensity (M-M)
Apr.				
20	04 43.4	39.9	175.5	IV
21	23 11.3	39.9	176.9	VI
23	09 45.6	41.6	175.8	IV
23	11 38.3	40.2	176.8	IV
23	11 41.3	41.0	172.9	II
23	23 51.4	46.6	169.0	V
24	09 26.2	46.7	169.0	IV
25	03 47.5	40.9	172.8	IV
25	04 11.7	40.9	172.7	IV
26	03 34.8	41.4	174.9	I
27	08 00ca	45.0	168.7	I
28	14 48.2	40.1	175.3	V
28	17 28.1	40.1	175.3	--
28	17 36.0	40.1	175.3	V
30	19 39.1	40.7	176.6	IV
30	22 52.9	41.5	172.0	I
May				
3	05 11.4	41.0	176.1	V
3	11 29.7	40.9	175.8	II
4	02 11.9	40.7	174.7	III
4	17 30.2	37.8	177.0	IV
5	02 05.5	39.5	175.3	V
10	11 56.8	39.2	176.8	-
11	07 50.6	34.5	178.5	I
12	03 17.8	39.8	176.2	
15	01 27.4	31.7	179.5W	
17	07 06.6	39.4	178.9	VI
17	15 45.7	39.4	178.8	V
17	18 32.7	39.3	178.7	-
17	21 26.7	39.3	178.8	III
17	21 35.3	39.2	178.7	III
18	08 15.2	39.3	178.8	IV
19	12 12.5	39.2	178.5	II
21	19 02.1	42.6	172.5	IV
22	15 01.0	39.0	178.7	IV
22	15 02.4	39.1	178.7	IV
22	15 04.5	38.9	178.7	?
22	15 24.8	39.0	178.5	II
22	15 51.5	39.0	178.5	I
22	17 25.0	39.1	178.8	V
23	09 35ca	39.0	178.7	II
23	12 16ca	39.0	178.7	II
23	18 35ca	39.0	178.7	II
24	09 33.1	39.0	178.5	IV
25	19 05ca	39.0	178.7	III
27	09 54.8	39.3	178.9	—
29	06 25.7	39.0	178.9	IV
29	19 05.3	39.0	178.8	II
31	15 36.7	41.2	172.2	III
31	18 31.2	41.3	174.2	IV
June				
2	13 54ca	39.0	178.8	IV
12	19 12ca	39.0	178.8	III
16	10 55.7	38.4	178.4	VII
16	11 00.4	38.4	178.4	III
16	11 20.5	38.4	178.4	II
21	17 27ca	43.2	171.4	II
23	19.42ca	39.0	177.5	III
27	14 43.1	40.7	172.6	III
30	16 15.0	38.9	179.0	III
July				
5	11 47.0	38.9	178.7	III
7	04 18.2	34.0	178.0W	--
9	18 11.2	40.8	172.9	III
11	05 09.0	39.8	174.4	III
11	18 55ca	39.2	177.5	II
11	20 05.0	41.1	173.3	—
13	19 58.5	43.3	171.2	II
17	06 00ca	40.9	172.8	II
19	08 41.5	39.1	177.8	III
23	07 31.4	37.7	178.8	--
23	16 51.1	40.8	176.2	III
24	11 38.9	39.1	176.8	—
30	23 37.5	39.9	173.4	
Aug				
2	13 46.9	38.8	177.3	IV
2	22 12.9	38.5	176.8	IV
2	22 40.0	38.7	176.6	IV
2	22 44.8	38.6	178.7	IV?
3	01 04.7	41.2	173.1	-
6	19 29.6	39.2	174.6	II
7	09 32.2	39.8	177.6	-
8	05 32.8	46.5	166.5	?
8	06 50.4ca	46.5	166.5	?
8	20 18.6	46.4	166.5	?
8	20 25ca	46.4	166.5	?
9	03 33ca	46.4	166.5	?
9	03 46.7ca	46.5	166.5	?
9	05 33.4	46.4	167.0	II
9	06 23.9ca	46.5	166.5	?
10	11 59.8	40.5	175.0	IV
10	22 28ca	38.5	177.5	III
14	13 39.2ca	46.5	166.5	?
14	17 40.5ca	46.5	166.5	?
14	17 51.5	39.1	178.5	II
15	22 34.1ca	46.7	166.6	?
17	06 48.1	40.5	175.0	IV
17	08 36.1	41.2	174.3	III
18	11 46.6	39.6	176.1	II
19	12 02ca	40.2	176.1	I
21	07 40ca	46.5	166.5	?
22	05 42.9	42.7	173.0	IV
22	13 46.9	38.3	177.8	V
22	23 59.2	38.3	177.6	VI
23	19 10.5	41.1	173.3	?
24	20 35.2	38.8	178.3	?
25	19 28ca	42.8	173.5	IV
26	03 38.3	38.1	177.9	V
26	12 12.5	40.1	174.9	IV
27	13 37.8	39.7	179.2	VI
27	16 20.9	39.4	179.3	IV
27	16 35.6	39.3	179.2	—
27	16 37.9	39.2	179.3	—
27	16 41.5	39.4	179.3	—
27	16 45ca	40.2	176.2	III
27	17 32.8	38.8	179.3	III
27	23 47.1	39.1	179.3	—
28	00 00.0	39.7	178.9	II
28	00 56.4	39.5	179.1	II?
28	03 00.7	39.4	179.0	--
28	08 12.8	39.0	178.9	II

Origin Time (G.M.T.)*		Epicentre:		Max. Felt Intensity
1947	h. m.	Lat.S (deg.)	Long.E (deg.)	(M-M)
Aug.				
28	15 07.1	39.3	179.0	II
28	17 10.5	39.2	176.0	—
28	18 17.2	40.2	176.0	—
29	00 25.9	38.7	175.7	—
30	01 59.3	38.8	178.8	II
Sept.				
1	08 02.6	39.7	178.9	II
3	08 19.6	39.5	175.9	—
3	16 43.0	41.9	178.5	—
4	14 05.5	39.8	179.1	III
8	01 16ca	45.2	169.2	VI
8	22 00.8	39.8	179.0	—
10	09 30	41.0	175.7	?
11	11 12.5	40.2	174.7	IV
14	14 35.0	43.3	171.5	IV
15	09 14.2	41.0	176.2	VI
16	14 47.2	41.1	172.1	
20	13 12.9	40.4	172.8	—
22	09 53ca	43.2	171.5	III
22	10 43.3	39.8	174.0	III
23	14 53.4	43.2	171.5	II
23	17 54.5ca	39.3	177.7	II
30	02 56.0	40.2	174.4	I
30	05 38.4ca	43.2	171.5	III
Oct.				
1	13 29.4	41.6	174.2	II
3	17 59.3	39.2	179.9	
9	01 09.9	38.8	178.8	III
9	23 19.6	40.5	173.7	III
10	04 15.4	38.9	178.9	—
12	10 11.7ca	37.3	177.5	IV
13	07 31.4	44.2	169.0	VII+
13	08 07ca	44.2	169.0	?
13	08 18.4	44.3	169.0	?
13	08 39.3	44.2	168.2	?
13	08 47.5	44.0	168.0	?
13	08 51ca	44.2	169.0	?
13	08 54.1	44.3	168.6	?
13	09 21.4	44.0	168.0	?
13	09 25ca	44.2	169.0	?
13	09 55ca	44.2	169.0	?
13	10 08ca	44.2	168.7	?
13	10 11ca	44.2	168.7	?
13	16 11.5	43.4	171.2	III
14	00 23ca	44.2	169.0	?
14	01 10ca	44.2	169.0	?
14	06 37ca	44.2	169.0	?
14	08 00ca	44.2	169.0	?
14	09 00ca	44.2	169.0	?
16	09 02.2ca	40.0	174.8	III
16	11 07.7	40.5	174.5	III
Oct:				
17	20 28.8	38.9	175.9	III
18	13 00.3	42.3	173.7	—
20	17 24.2ca	41.7	171.5	IV
22	15 25.4	38.7	178.5	IV
23	13 54.0	38.5	176.8	IV
25	03 33.1	37.9	176.9	III
26	09 28.8	40.1	175.6	III
26	11 57.9	39.8	174.9	IV
27	07 12.6	38.0	178.0	III
27	07 30.4	38.0	178.0	III
29	09 40.8	46.5	167.5	III
31	00 50.4	38.2	176.8	?
Nov				
1	03 17.5	38.7	178.6	II
1	13 25.4	40.6	173.1	—
4	09 07.8	38.6	178.8	III
4	09 12ca	38.6	178.8	II?
5	19 54.0	40.1	175.0	II
6	03 39.5	44.3	168.6	V
8	22 41.2	39.5	179.3	IV
8	22 43.9	39.6	179.3	—
9	02 04.6	39.6	179.7	—
9	16 02.9	41.2	175.1	IV
15	08 28.0	39.1	176.2	—
18	22 25.6	44.3	169.0	III
22	04 56.1	40.9	172.8	II
23	21 40.7	41.5	172.5	—
25	18 43.4	41.5	172.3	II
25	23 59.0	38.6	176.1	III
27	05 25.8	41.3	175.8	II
Dec.				
3	16 37.5	37.9	177.6	IV
4	20 46.6	36.5	177.9	—
5	23 21.1	35.5	178.0W	—
6	01 06.1	42.0	172.5	—
6	19 35.6	41.2	173.4	III
10	07 13.3	41.8	174.5	—
11	10 59.2	41.5	173.7	III
11	11 20ca	40.9	172.5	II
11	14 20.6	40.9	172.5	IV
12	14 38.4	40.8	174.6	I
15	13 17.4	40.0	175.2	IV
15	14 21.1	38.8	176.3	—
18	07 10.2	39.6	175.9	I
19	16 04.1	38.6	176.6	—
22	14 53.6	39.4	176.8	III
26	02 40.2	38.2	176.9	II
28	17 30.3	40.6	172.4	V
29	14 54.5	41.4	174.8	II
31	17 08.2	38.6	177.8	IV
31	22 26.4	38.4	175.8	—

* G.M.T (Greenwich Mean Time) is 12h. 00m. slow on New Zealand Standard Time.


NEW ZEALAND
SHOWING
EPICENTRES OF PRINCIPAL EARTHQUAKES IN 1947
Epicentres correct within 15 miles approximately
Focal Depth Normal
Epicentres possibly 15 miles or more in error
Focal Depth Normal
Seismograph Stations
SCALE
AUCKLAND
New Plymouth
Arapuni
Tuai
Hastings
Bunnythorpe
Takaka
WELLINGTON
Kaimata
CHRISTCHURCH
DUNEDIN
Monowai
Hawke Bay
Approximate Isoseismals, Earthquake of 1947 June
1947 March 25 20 32 G.M.T.
1947 October 15 07 51 G.M.T
Approximate Isoseismals for the Earthquakes of 1947 March 25th and October 15th

SOME FEATURES OF LAVA CAVES AT PENROSE, AUCKLAND, N.Z.

By E. J. SEARLE, Auckland University College

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Summary

The occurrence of an extensive system of lava caves at Penrose is recorded and the formation of some interesting lava-drip formations associated with them is described.

THE later effusions of lava from the Mt. Wellington volcanic centre took place from its eastern face and spread as a flood-like sheet as far to the north-east as the low hills of Tertiary sandstone on which the links of the Remuera Golf Club are situated. The flood then deviated, as earlier ones had done, into a low-lying area that extended as far southwards as Manukau Harbour where it added its material to the building of a considerable lava field to which Mt. Smart, and, to a lesser extent, Mt. Richmond and One Tree Hill, also contributed lavas. It is not easy today to draw definite boundaries between the flows emanating from these different centres, but it seems fairly clear that the uppermost flows from Mt. Wellington approached but did not cross the line of the Great South Road.

The lava seems to have spread in a series of relatively thin flows by pushing out long and narrow tongues which advanced in amoeba-fashion over the lava field already built up by earlier extrusions from the same centre. The lava itself was extremely fluid, for although individual flows seldom show thicknesses greater than 20 feet they extend south-east for a distance of two miles from their source with a surface fall of only 50 feet.

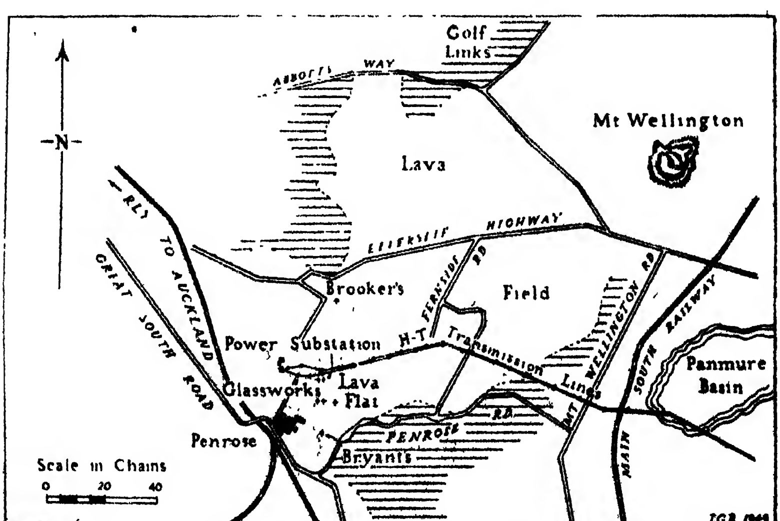


FIG. 1.—Map showing the location of the main Penrose caves. The approximate boundary between the lava field and the sedimentary terrain (ruled) is shown by a broken line.

On the south-west the main flood made contact with low sandstone hills to the south of Penrose, where the road follows the boundary between the lava field and the sedimentary terrain for some distance. From the vicinity of the Power Sub-station a narrow tongue of lava some 10 chains wide advanced for about half-a-mile southward towards the junction of Penrose Road and Great South Road thus enclosing between it and the main sheet a basin of approximately 500 yards by 300 yards in extent which was floored by older lavas from Mt. Wellington.

Lava caves and collapse features almost certainly associated with caves beneath the surface are widely distributed in both the older and younger flows. Caves similar in type are by no means uncommon in the lavas of other of the Auckland volcanoes, well-known examples being those on Rangitoto Island, at Three Kings, and at Onehunga in the flows from One Tree Hill. Those described in this paper, however, are all associated with the southern lava tongue referred to above, and differ from any ot the others examined both in their extent and in certain peculiar features to be discussed later.

The Penrose caves as they exist today represent only a small part of their former extent as is clearly shown by their dismembered character and by the evidence of collapse general throughout the whole of the wide area in which they occur. The largest collapse feature is a broad chasm about 100 feet wide, 30 feet deep and nearly a quarter of a mile long which passes up through the centre of the tongue of lava already mentioned. Its floor consists of jumbled blocks of basalt and its walls are steep breaks or masses of fallen blocks with the openings of caverns in several places. On the surface of the flow and trending parallel with the edges of the chasm are several lines of dislocation showing up either as open fractures, one of which is nearly a foot across, or as bands two to three feet wide consisting of broken basalt blocks.

At its southern end the collapse trench becomes far more complex, and its form has been considerably modified by quarrying operations in a number of places. At least eight caves have their entrances in this southern part of the collapsed area where the upper surface of the flow is exceedingly broken by troughs and by pits, at least three of which pass down by narrow shafts into caves beneath. It would thus appear that the greater part of the southern end of the lava tongue concerned has been completely undermined by a network of caverns and tunnels and that the roof rock has in large part collapsed, filling in most of them and leaving only a small remnant of the former network as open caves today.

Two of the caves are described below and are fairly typical of the rest.

Glassworks Cave

Map ref. 337536, Tamaki Sheet, N.Z.1/25,000.

The main entrance to the cave is through an opening 25 feet wide and 5 feet high in the south-westerly face of a quarry-enlarged collapsed area situated behind the factory of the N.Z. Glass Manufacturers' Co. Pty. Ltd., Great South Road, Penrose. The top of the entrance is about 15 feet below the general surface of the lava flow and its bottom is roughly level with the roof of the large chamber to which it gives access.

This latter trends nearly north and south for 90 feet, has a maximum width of 30 feet and a height of 15 feet. The original floor is covered by large blocks which have fallen from the roof and walls and the roof consists largely of basalt broken into irregular and angular blocks by joint planes. Near the entrance, however, the roof is not so broken and is there made of slaggy scoriaceous material showing flow-streaking on its surface which clearly represents the under surface of a lava flow. Beneath this surface, on the south side of the entrance, there is a thin layer 4 inches to 5 inches thick of a red, partly-baked but friable tuff, an association that is repeated almost everywhere this lower surface of the upper lava flow is exposed. It appears, for example, at the southern end of the main chamber of the cave now described where a side-opening leads upwards into a small upper grotto about 12 feet high and the same in diameter. At this point, too, the cave branches; the main cave continues southwards for a further 20 feet and the floor then rises on the steep slope of a rockfall to the bottom of an open vertical shaft, 30 feet high and 7 feet wide at the top. Further original extension to the south is clearly shown by collapse on the surface, but, debris that fell when the shaft was formed has caused a complete blockage.

The other and much smaller branch originates from the main chamber near the base of the shaft and bears off in a westerly direction; it is 12 feet wide and 5 feet high near its opening, but soon narrows to a width of only a few feet. It can be followed for a distance of 50 feet while its floor descends continually and finally drops abruptly into a pit 9 feet deep and 12 feet wide. The bottom of this pit, like that of the passage, is deeply covered with fallen blocks, while falls of rock have also come from the roof, yielding a dome with its ceiling about 6 feet higher than that of the passage. The lateral cavern continues on the other side of the pit but it is too narrow and its roof too dangerous to permit examination.

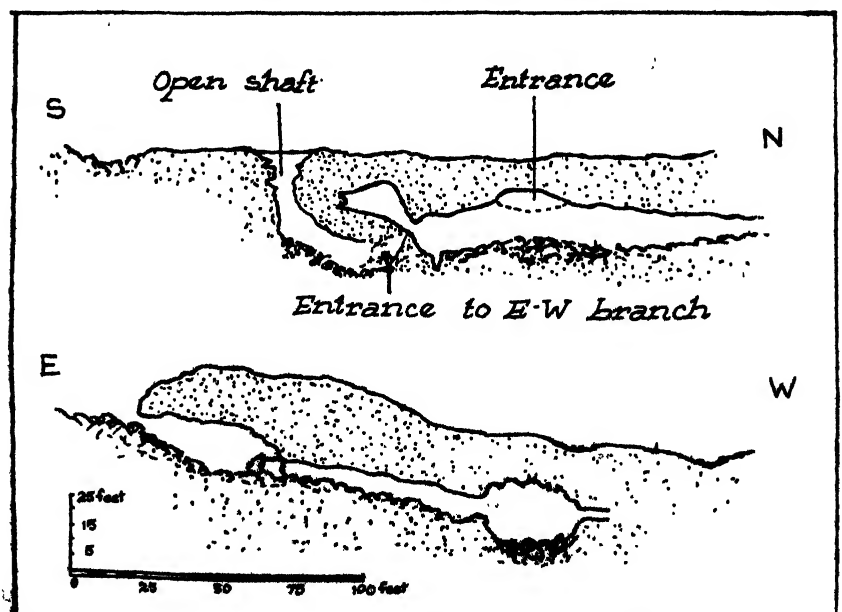


FIG. 2.—Profiles of lava caves situated east of the glassworks, Penrose.

The sketches of Fig. 2 give some idea of the profiles of the main chamber and of the side cavern.

Caves near Power Sub-station

This group of caves is located just below the first pair of closely-placed pylons on the east side of the Penrose Power Sub-station (map ref. 337542, Tamaki Sheet, N.Z.1/25,000) and is almost at the head of the lava tongue referred to above. Their entrances are in wide collapse pits in line with the main collapse trench and only a few yards beyond its northern end. The opening into the main cave is about 15 feet below the surface of the flow and is 10 feet wide, by 5 feet high, and leads down over a steep slope of fallen material into the side of a north-south trending chamber with its floor some 18 feet down. At the northern end the floor descends steeply into a much larger cavern trending east-west and measuring approximately 60 feet in length by 40 feet in width, with a height of almost 20 feet. The floor continues to descend steadily and fairly steeply to the west and is almost completely covered with fallen blocks which in places aggregate to a thickness of at least 12 feet. Collapse has not been as considerable on the northern side as elsewhere so that the floor is higher and the roof lower; as in the glassworks cave this latter is the slaggy under surface of a flow and rests upon a layer of pinkish tuff which shows poorly-developed prismatic jointing and is occasionally fused to the surface of the lava above. This same relationship is shown again in a large cave (Brooker's) situated half-a-mile further north near the corner of Eaglehurst Road and Ranier Street, Ellerslie, where, however, the tuff is much coarser and in a thick band which shows quite coarse prismatic shrinkage joints.

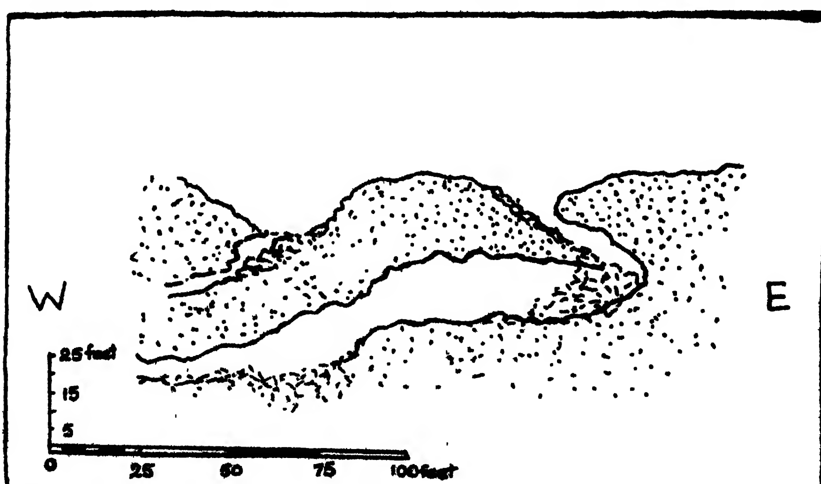


FIG. 3.—Profile of large lava cave situated east of the Power Sub-station, Penrose.

The contact between the upper and lower flows in the sub-station caves is, as would be expected from the character of the extrusions, a very irregular one, for there is a very uneven surface on the lower flow.

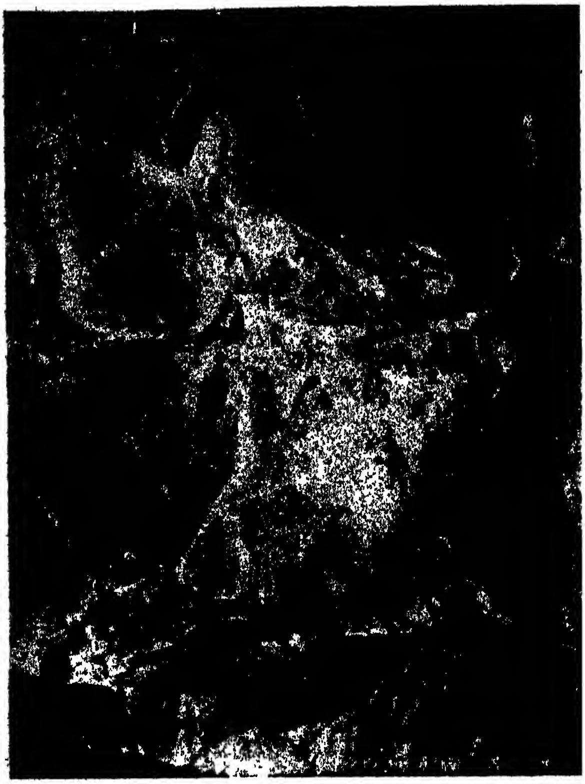


FIG. 4.—Upper part of north wall and roof of cavern facing the rear of the glassworks, showing festoons of small drip stalactites hanging from the roof and, in the left centre, an area where a softened surface sheet of rock has sagged back as a flap attached along one edge exposing fresh rock beneath.

On the southern side of the cave two tuffaceous layers may be traced for a short distance and indicate that possibly a third lava flow is present. The cave was not followed far beyond the western end of the big chamber, for rockfalls of recent date render it unsafe, but apparently at this stage it passes below a second wide collapse pit in the surface of the flow. A further smaller cave has its entrance at this pit; it descends steeply but was not followed far. Although it was not definitely established that it joins the main cave, there can be little doubt that it does so.

About 100 yards north-west from the pylons there is a small lava-floored flat which occupies a basin between two lava tongues. It, also, has small caves opening under its edges and many closely-spaced collapse pits on its surface. It is probable that the system of caves described above extends below this lava flat but at a greater depth than the small marginal caves just noted.

Fluxional Features Associated with the Caves

Most interesting evidence of the fluxional action of hot gases is afforded by several of the caverns in the southern end of the system. A striking example occurs in the mouth of a cave facing west and situated about 50 yards west of that already described in the rather

complex collapse area behind the glassworks. Its entrance is wide and low and leads into a cavern 7 feet high and 15 feet wide with its floor only a few feet below the entrance level. A layer of tuff 5 inches thick is exposed at the base of the southern wall, while on the northern side there is an opening low down which leads down a rockfall slope into a lower but much more extensive cave which can be followed east for 60 feet before it becomes too restricted for travel. Evidence of hot gas action is confined to the upper chamber of the cave and is best afforded by the rock of the roof and of the walls on the northern side, and by the face above the entrance to the lower chamber. Over these areas a glazed surface has been produced and some degree of fusion has led to the rounding of the edges of all the joint blocks. The softening appears to have taken place to a depth of about an inch beneath the present surface, for in several places the crust of softened rock has sloughed off exposing normal rock beneath. One patch where nearly a square foot of the superficial layer of softened rock has sagged away can be seen on the left in Fig. 4. Part of the sloughed crust peeled back and froze while still attached along one edge, an effect which can be observed in several other instances. That there was re-melting as well as softening is clearly shown by the festoons of tiny, drip stalactites

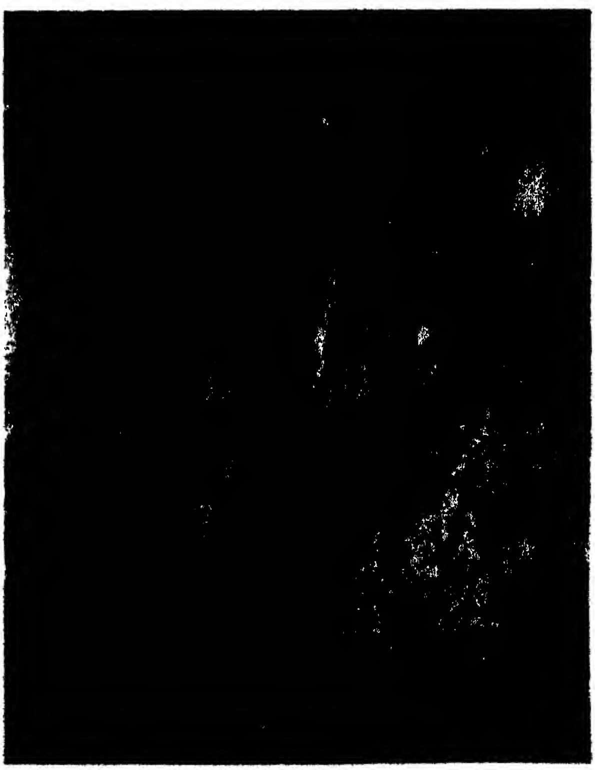


FIG. 5.—Southern wall of small upper chamber of same cave as in Fig. 4, showing frozen lava trickles, some of which terminate in drip stalactites and others in a small rippled terrace formation. The vertical height shown in the photograph is 4 feet.

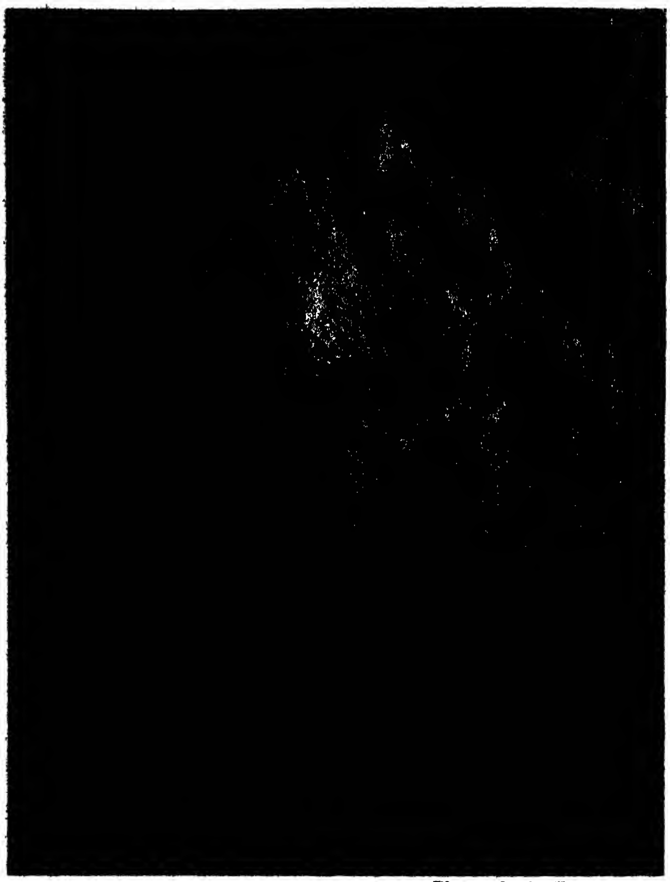


Photo: J. A. Bartrum

FIG. 6.—Rippled surface of remelted basalt near southern portion of the same cave as in Fig. 4 directly above the entrance to the lower caverns. Height shown in the photograph is 3½ feet.

which hang from the roof and from ledges on the walls (Fig. 4). Elsewhere, and particularly over the entrance to the lower chambers, the rock was rendered so fluid that it trickled down the walls of the cave in tiny streams like candlegrease down the sides of a candle. As it began to cool, the lava of these trickles piled up in tiny, rippled terraces on ledges or at the foot of the wall. The effect is well shown in the flashlight photograph, Fig 5, and in Fig. 6.

The drip stalactites formed from the roof and from ledges on the walls are generally narrow, solid teat-shaped bodies two or three inches long usually with a glazed exterior. Sometimes adjacent stalactites have coalesced laterally to form larger irregularly-shaped ones but none of them are more than a few inches long. The three shown in Fig. 7 are typical of those commonly found in the caves.

Stalactites are found in several of the other caves examined but not in the same profusion as in this glassworks one. The only other place, however, where lava 'trickles' were observed was near the mouth of a small cavern about 50 yards east of this last cave and almost certainly merely another entrance to it.

Where re-melted rock has dripped down, the fallen drops have formed irregular heaped-up masses lower down. The drops usually hardened sufficiently as they formed or whilst they were falling to maintain something of their initial individual tear-drop shape, though hot enough to agglutinate. The best examples of these lava drip formations were obtained from a locality a quarter of a mile south of the glassworks caves, from caves just south of the working face of Bryant's quarry, Penrose Road. These latter are too small to enter and are very narrow irregularly-branching passages that are offshoots of a much larger one now destroyed by quarrying. Several fine drip phenomena were obtained from the entrance; one specimen, a portion of which is shown in Fig. 8, consists of a thin slab built out as a small shelf across the throat of a more or less vertical passage and has been built up of blobs of lava which have dripped from above, often preserving the tear drop shape.

Where the drip of lava has been on a smaller scale or has taken place more slowly from more isolated centres, the drops have built up small stalagmites from floors or ledges such as is well shown in Fig. 9 which comes from a cave at Bryant's quarry. Its individual drops are about an inch long and up to half an inch in diameter while their surfaces are generally glazed or smooth though sometimes covered with tiny blisters; there are often large vesicles beneath the glazed crusts (see Fig. 10). Professor Bartrum has kindly made available the photograph (Fig. 11) of a beautiful stalagmite from Takapuna which is much larger than any of those so far obtained from the Penrose caves and appears to have been made by more fluid lava, for the drops have elongated much more than is usually the case in the Penrose area.

A further and most unusual type of drip formation was shown during March, 1948, in the working face on the western side of Bryant's quarry, just north of the small cave and at approximately the same level as its entrance. Fifteen feet below the top of the face and passing right across it, there is a definite break in the basalt. On the northern side it takes the form of a thin layer of tuff on which rests the slaggy under surface of a flow. Through gaps in the face, narrow and very irregular

FIG. 7.—Small stalactites from the caves at Penrose.

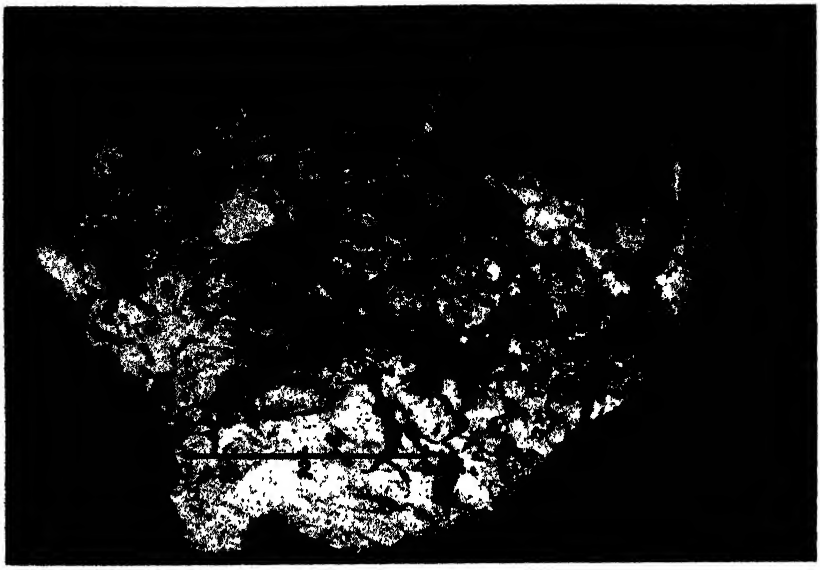


FIG. 8.—Upper surface of lava-drip formation from cave at Bryant's quarry, Penrose. Photo: J. A. Bartrum

passages can be seen while the rock above the tuff often consists of lava-drip slabs with small stalactites or hanging drops with baked tuff clinging to them (Fig. 12). Further south the break is made by a band of solid rock 2 feet thick which is traceable for 20 feet and is composed solely of firmly agglutinated drops; it represents, therefore, what may be called a 'stalagmitic' or 'lava-drip rock' (Fig. 13). It seems safe to assume that the rock has been formed by drops that have resulted either from remelting of the material of the roof of a shallow cave, or by liquid lava oozing through orifices from the lava sheet above, but it is difficult to explain how such a fissure could be so completely filled by dripping from directly above. It is probable that the drops originated in an open part of the cave, either behind the face or in a part of the flow now removed by quarrying, in which the dripping of lava was on a more liberal scale than elsewhere and that the mass of soft drops has slumped down into its present curious location.

The following general conclusions may be made as a result of this short investigation:—

1. The final effusions of lava from Mt. Wellington occurred in the form of thin flows which spread out in long and comparatively narrow tongues over the lava field formed by earlier outpourings.

2. The last major outflow was preceded by an explosive eruption from either the same vent or vents as gave rise to the flow or from others near them which scattered a thin covering of tuff over the older surface.

The final outflow followed quickly upon the preceding one, for evidence at Wilson and Rothery's quarry, Ellerslie, suggests that the lower flow was still quite hot when the upper one was spread over it.

3. An important feature in the advance of the lava floods was the outflow of lava from beneath a solidified crust resulting in the formation of caves and the weakening of crustal support facilitating collapse. The chief difficulty is to explain the formation of caves that extend through

FIG. 9.—Small lava stalagmite from cave at Bryant's quarry, Penrose.

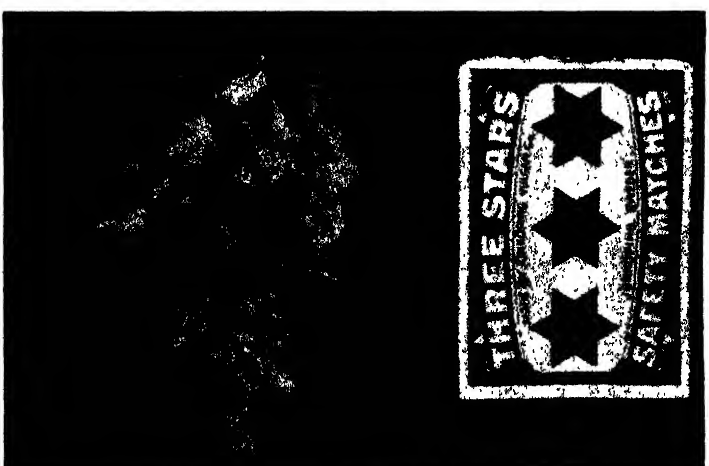


FIG. 10.—Small lava-drip structure—probably a stalactite—from Bryant's quarry, Penrose. Note the large vesicles in the broken drops in the centre. Photo: J. A. Bartrum

FIG. 11.—Large lava stalagmite from floor of a small cavern at Smale's quarry, Tauhuroto Road, Takapuna. Photo: J. A. Bartrum

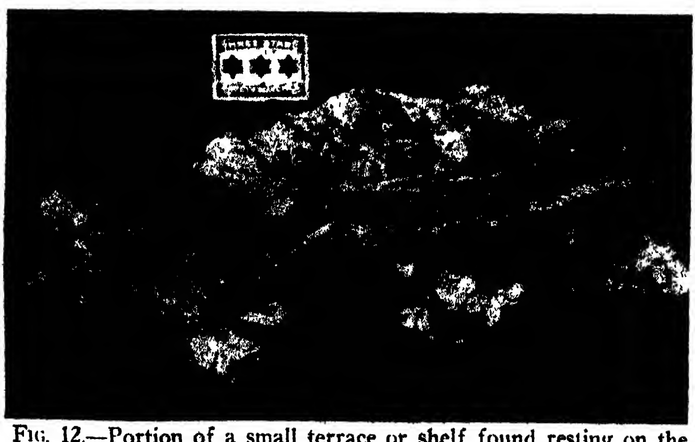


FIG. 12.—Portion of a small terrace or shelf found resting on the tuff layer at Bryant's quarry and showing the toes of lava trickles on its upper surface and irregular stalactites on the lower. The dark material on the lower surface is adherent baked tuff. The specimen is 5 inches from front to rear.

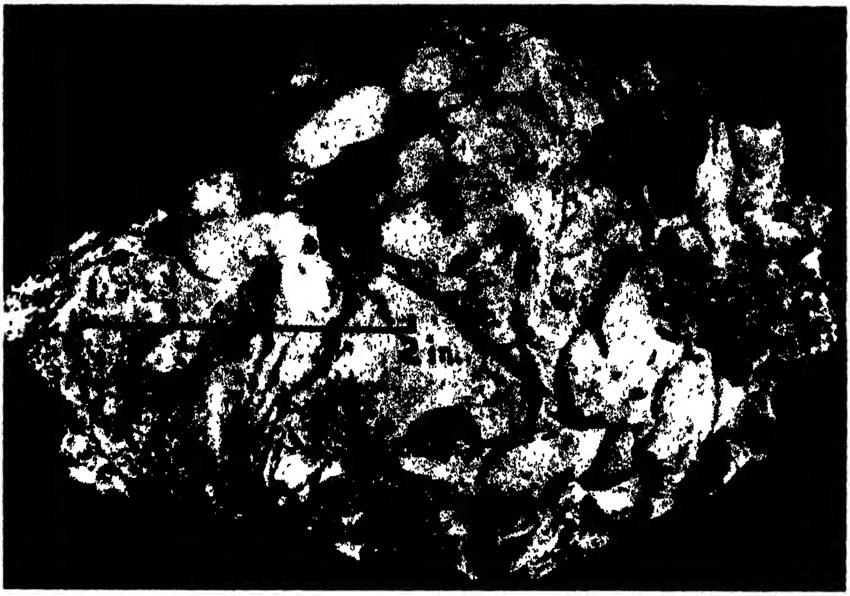


FIG. 13 – Lava drip rock taken from the face at Bryant's quarry, Penrose. Photo: J. A. Bartrum

superimposed flows or that are roofed by the upper flow. Why has the lava of the upper flow not flooded down into the caverns beneath and effectively sealed them? The caves at Penrose are so large and the network of them so completely undermines the area that some such effect would certainly be expected. It is possible, though unlikely, that draining off from the lower levels did not occur till after the upper flows were emplaced. Certainly there is little evidence of withdrawal of lava from the upper flow on anything like the scale that has obtained in the lower.

It seems most probable that the caves or tunnels were almost completely confined to the lower sheet and that the major collapse was largely provoked by the weight of the upper flow spread upon it and took place after this latter was substantially solid. The upper flow now forms the roof of many of the caves probably as a result of collapse of much of their original cooled carapace with the assistance of waters percolating freely through the tuffaceous layer that is present.

The various drip phenomena described almost certainly are to be ascribed to remelting of lava that earlier has been substantially solid, for at the glassworks caves joint blocks of the upper flow have had their edges softened and thereby rounded. Even at Bryant's, though the evidence is not so definite, this appears also to have been the case. It seems impossible to avoid the conclusion that hot gases responsible for the remelting came through the caverns and originated either in the lava of the lower flow or in lavas that had come from above into the caves or tunnels of this lower flow.

ACKNOWLEDGMENT

The writer wishes to acknowledge gratefully the assistance and encouragement of Professor J. A. Bartrum in the preparation of this paper.

GEOMAGNETIC LATITUDES AND REGIONAL ANOMALIES IN NEW ZEALAND AND THE SOUTH PACIFIC

By W. M. JONES, Dominion Observatory, Department of Scientific and Industrial Research, Wellington

(*Received for publication, 10th November, 1947*)

Summary

For an axis-pole at 78.5° S., 111° E., parallels of geomagnetic south latitude are shown at 1° intervals for New Zealand, and at 5° intervals for the region 0°-75° S., 150° E -155° W. Regional anomalies in New Zealand, in respect of the theoretical field from the centred dipole, for inclination and horizontal force, are illustrated by a comparison of this field with the actual distribution observed by Farr.

GEOMAGNETIC LATITUDES

LOCAL values of geomagnetic latitude are often required in studies of aurorae, ionospheric phenomena, cosmic rays, as well as for the consideration of regional anomalies in the different components of the magnetic field. Values for the magnetic observatories are available, but it is convenient, for work in a particular region, to be able to obtain at a glance, with sufficient accuracy, the value at any point in the region. A diagram has therefore been prepared for the New Zealand region, 34°-48° S., 166° E.-180°, (Fig. 1), showing the geomagnetic parallels at 1° intervals, from which the value at any point can be read off to about 5′, and another for a portion of the South Pacific, 0°-75° S., 150° E.-155 W., (Fig. 2), which will enable an estimation within about half a degree. For the first diagram (a conformal conic projection) the geomagnetic latitudes, which are the complements of the great-circle distances between the axis-pole and given points, were computed to an accuracy of about 1′ for a graticule of points at 2° intervals in geographical latitude and longitude, and the 1° parallels drawn by interpolation ; for the second (with the geographical latitudes and longitudes as rectangular co-ordinates) the graticule-intervals were 5°, and the parallels have been drawn at 5° intervals. This is not an ordinary method of map projection, but some of the more important towns and islands are indicated for convenience.

The axis-pole was taken as 78.5° S., 111° E., (Bauer's value for epoch 1922), its direction-cosines being : a = −.0715, b = +.1861, c = −.9799. Afanasieva(1) has recently given the value 78° 22′ S., 112° 44′ E., for the epoch 1945, as the result of a harmonic analysis of the latest data. To what extent the difference is real or a result of improved data is not certain. However, as a degree of longitude at the latitude 78.5° is equivalent in distance to only a fifth of a degree of latitude, it can be seen that the differences in geomagnetic latitudes from these two positions of the axis-pole will not exceed 0.3°.

REGIONAL ANOMALIES IN NEW ZEALAND

Regional anomalies being defined as departures of the actual field from the theoretical field from the assumed dipole, it is of interest to see what they amount to in New Zealand, and for this purpose the dipole

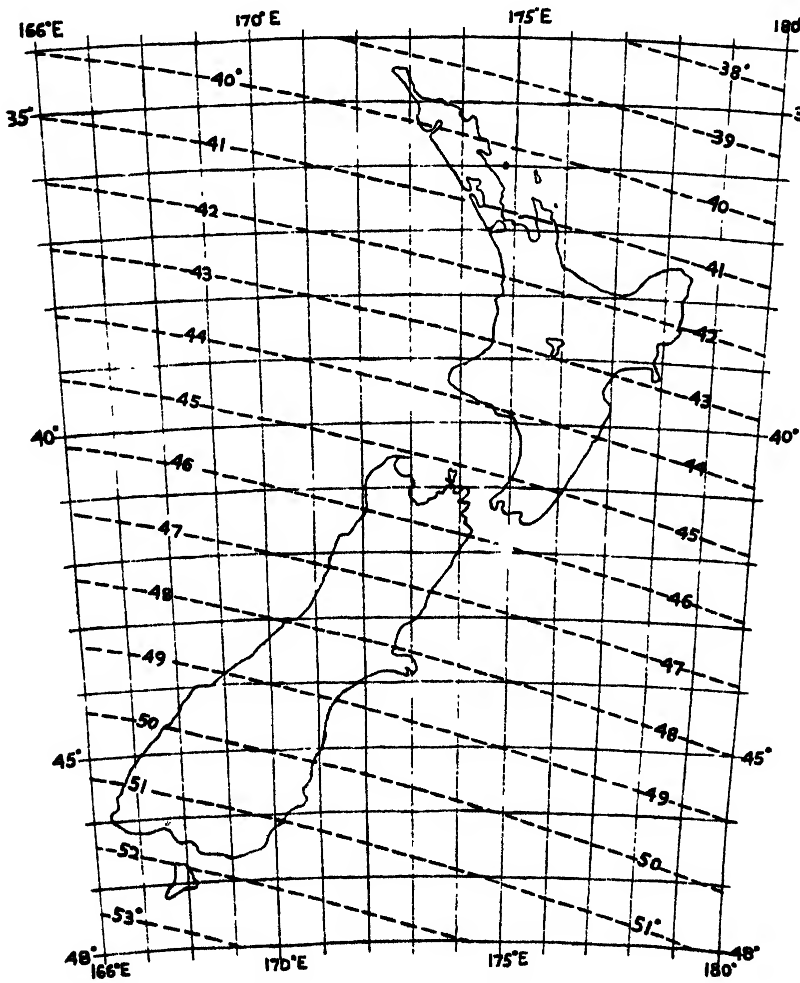
fields for inclination and for horizontal force have been compared with the smoothed fields for the epoch 1903 as depicted by FARR(2). For a centered dipole, the inclination I at a point of geomagnetic latitude ϕ is given by :—

$$\tan I = 2 \tan \phi,$$

and the horizontal force by : -

$$H = H_0 \cos \phi,$$

where H_0 is the value on the geomagnetic equator. H_0 has been taken as 0.335, or 33,500 gammas (3).



GEOMAGNETIC LATITUDES
for axis-pole at 78·5°S, 111°E.

FIG. 1

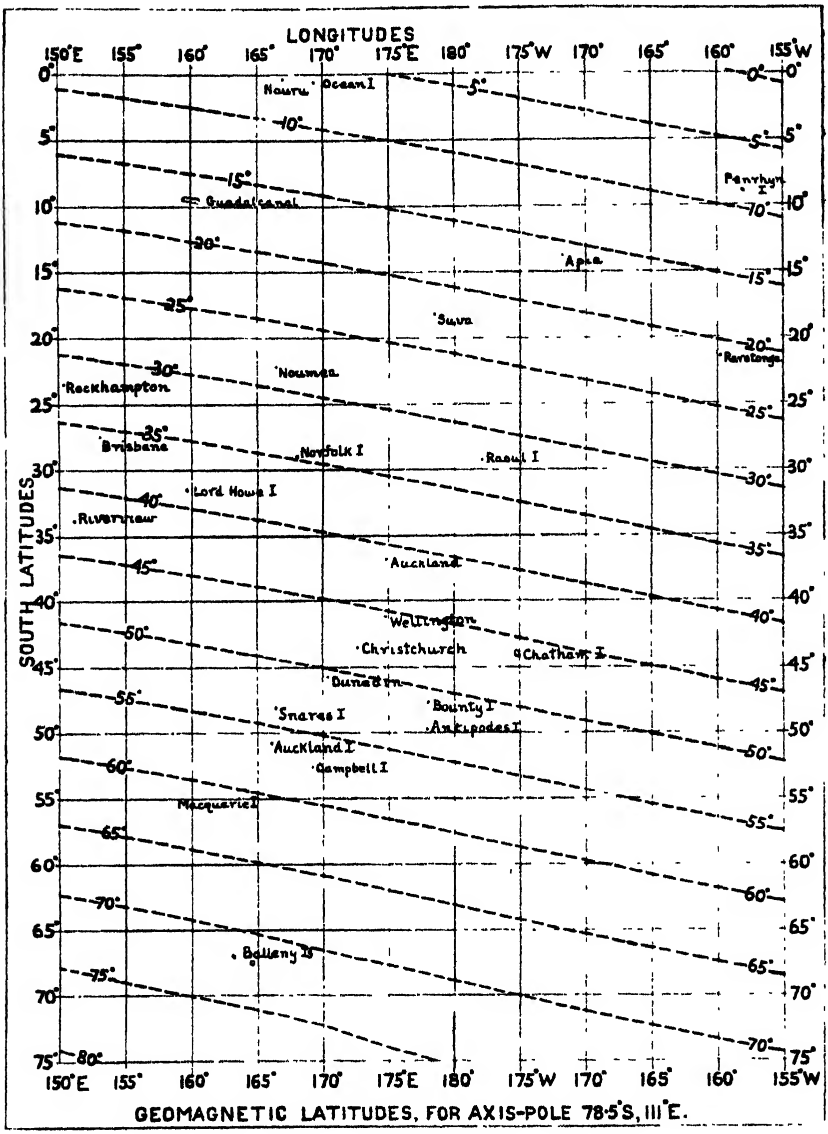


FIG. 2

In Fig. 3, Farr's values for inclination are compared with the computed values. Pending publication of the results of the recent magnetic re-survey of New Zealand, corrections have not been made for secular variation between 1903 and 1922. For the period 1905-1916 the average variation was estimated by Farr as + 1.86′ per annum. This would make an increase of some 35′ on the observed values as illustrated, but there is no certainty that this increase would be uniform over the whole country. In the figure the observed field is seen to be everywhere greater than the computed, the differences ranging from about 1° at North Cape to more than 2° at Stewart Island. The lengths of the arrows which connect corresponding isoclinics illustrate the differences. The addition

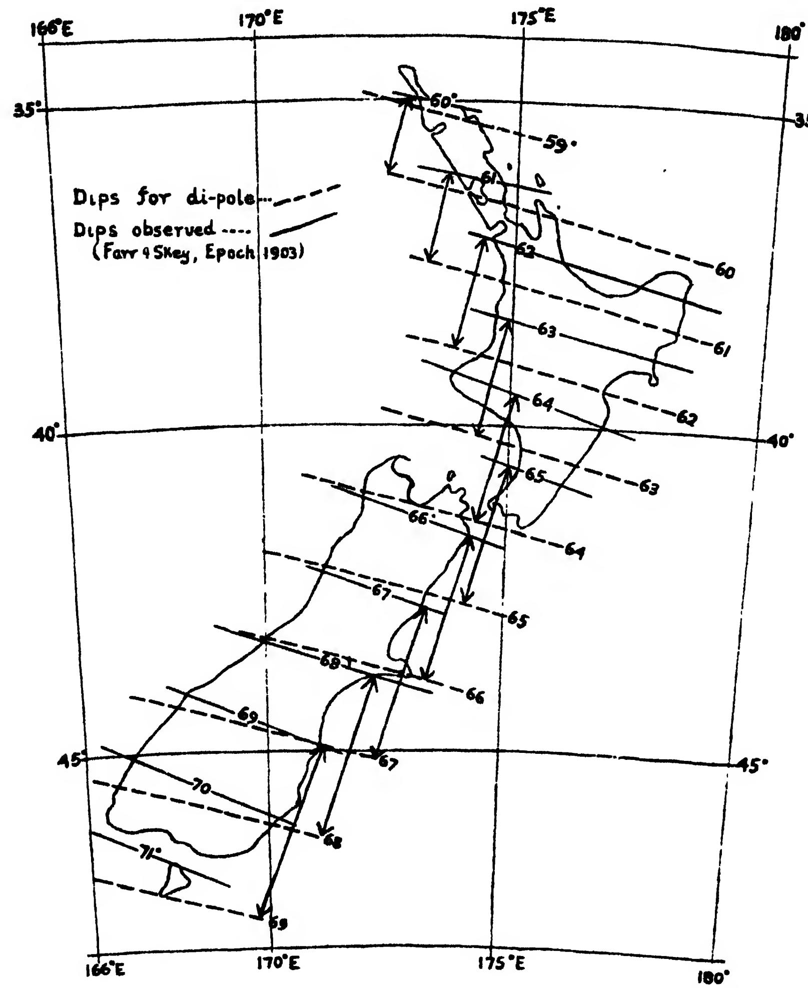


FIG. 3

of the 35′ for secular variation would increase the differences. It may be noticed that while the two values could be made to coincide at Stewart Island by bringing the southern axis-pole some 3.5° nearer, this would over-compensate at the North Cape by about 2°. The two sets of isoclinics are seen to be nearly parallel in the North Island, but diverge by about 10° in Otago.

In Fig. 4, without correction for secular variation, the values for H are seen to be about the same in Central Otago; farther north the observed values become steadily greater than the computed, the difference reaching some 1700 gammas in North Auckland, while to the south they become less, by some 350 gammas in Stewart Island. Bringing the southern axis-pole nearer would diminish the computed H-values, and thus further increase the differences over the North Island and most of the South Island. While the computed H-values depend on the value 0.335 taken for H_0, it is apparent that no adjustment of this could make a satisfactory co-incidence of the isodynamics over the whole country.

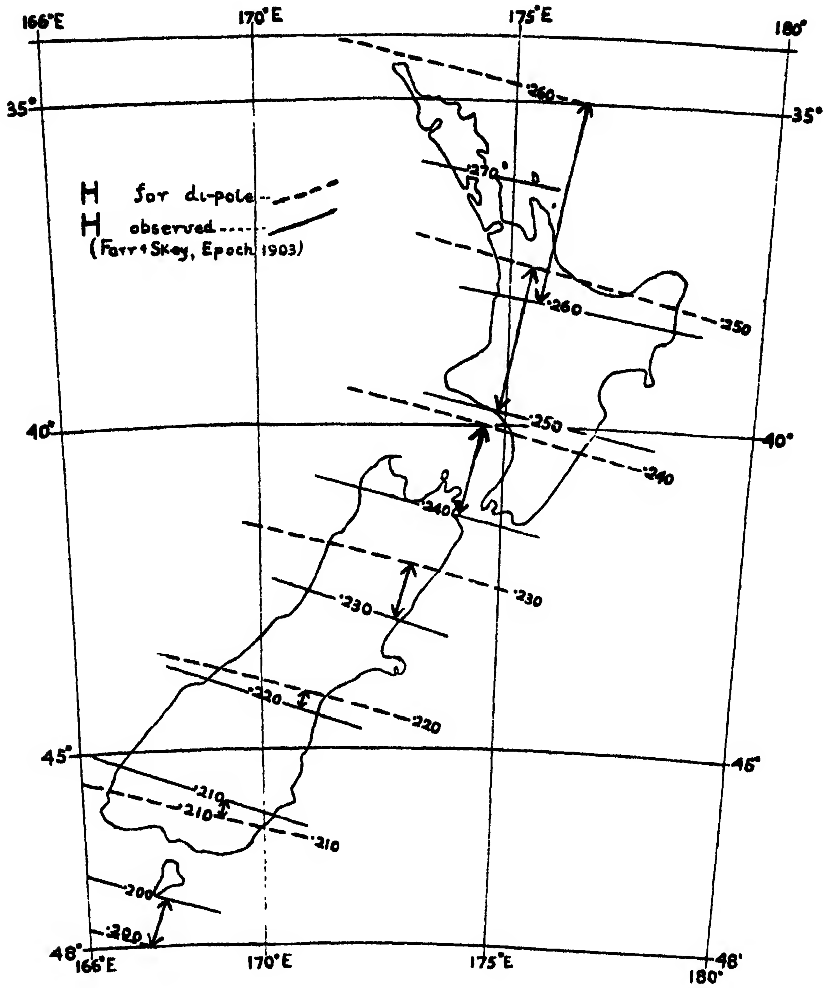


FIG. 4

Farr's estimated rate of average annual variation of H for 1903-1916 was —23 gammas. Extrapolating this to 1922, the correction to the observed values would be —437 gammas; this again might not be uniform over the whole country. Its application would diminish the differences, north of Central Otago, but they would still be some 1200 gammas in North Auckland.

CONCLUSION

The above will serve to draw attention to the existence of regional anomalies as defined. A more detailed picture could be obtained by considering the individual stations of the survey, and drawing iso-anomalies from the individual anomalies disclosed, but as some of Farr's stations are now known to be at points of considerable local anomaly, and as the secular variation corrections to the present time are rather doubtful, it will be better to await the results of the recent re-survey, and then to compare them with Afanasieva's analysis for 1945.

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TARARUA RANGE SUMMIT HEIGHT ACCORDANCE

By H. W. WELLMAN, Geological Survey, Department of Scientific and Industrial Research, Greymouth

(Received for publication, 29th September, 1948)

INTRODUCTION

WHILE studying the north-west Nelson District I discovered that the major structural features were defined by the height of the trigonometrical stations shown on the Lands and Survey Department's 4 mile sheets. By considering these trigs alone and generalizing them by means of contours it was possible to produce a structure map of the peneplain cut across the undermass in this area. The method was so simple and effective that it appeared worthwhile to see if it could be applied to other parts of New Zealand. The result showed wide variations in some areas such as Central Otago where peneplained schist surfaces are known, accordance was poor, but other areas such as the Kaikoura Ranges, South Canterbury, and North Otago showed features of structural significance. The most striking accordance was obtained from the mountain range at the south end of the North Island, extending north from Cook Strait to the southern end of the Ruahine Range.

I discovered this summit height accordance in 1939 and had hoped to be able to do some field work in critical areas, but pressure of work has prevented this and the present brief note is based solely on the 4 mile map and on published papers. It being considered better to publish an incomplete paper now, rather than promise a fuller one in the indefinite future.

PREVIOUS INVESTIGATIONS

Despite its proximity to the City of Wellington the south end of the North Island has not been geologically examined in detail. McKay (1879, 1888) gave the first detailed account of the indurated sandstones and siltstones (greywackes) that form the Tararua Ranges and the Wellington Peninsula. Although no diagnostic fossils have been found these rocks are probably the same age as similar lower Mesozoic rocks on the east side of the Southern Alps in the north end of the South Island. They are complexly folded and faulted and contain thin quartz veins. Conspicuous interbedded lava flows and tuffs occur at several places, but have not been traced far enough to throw much information

on the structure. The direction of the fold axes is not well known, but the available information makes it probable that this direction will not be very different from that of the present mountain ranges. Several physiographic accounts of the Wellington Peninsula have appeared—the first were by Cotton (1912, 1914, 1922), and later accounts have been given by Gage (1940) and Hall (1946). The absence of fossiliferous sediments above the greywacke undermass makes it impossible to date the numerous events in the later physiographic history of this area described by these authors. Fossiliferous beds extend along the eastern side of the Rimutaka-Tararua-Ruahine ranges from Palliser Bay north, detailed examinations having been made by Ongley in the Eketahuna Subdivision and by Lillie and others in the Dannevirke Subdivision. Although the mapping of both these subdivisions is complete, neither the final maps nor the bulletins have been published, descriptions of the areas being confined to short accounts and a small scale map of Eketahuna Subdivision given in the annual reports of the Geological Survey.

The trig stations shown on the 4 miles to the inch sheet represent an unbiased selection of high points. In drawing the generalizing contours an attempt was made to represent the most regular surface at a minimum height above these points. The significance of the contours depends on the average differences shown by the trigs and the contours. The following table shows these differences, averaged irrespective of sign for the Rimutaka and Tararua ranges, the areas between each of the successive 1,000 ft. contours above the 2,000 ft. contour being considered independently.

Contour Interval.	No. of Trigs.	Average Difference in Feet.
2-3,000 ft.	42	210
3-4 000 ft.	20	195
4-5,000 ft.	6	110
5-6,000 ft.	4	180

It will be noticed that the difference decreases up to the 5,000 ft. contour and then increases again. With the exception of Kapakapanui (3,615 ft.) eight miles east of Paraparaumu, no trig stands an appreciable height above the surface, and the differences are no doubt due in large part to recent erosion since the last uplift. There is little doubt that the structure shown by the contours is geologically significant, and they must represent a deformed surface that had considerably less relief than the present ranges have. Nevertheless, although there is little doubt about the significance of the whole structure, the trig points are insufficiently close to make the height of the surface definite in any small area, particularly near the margins. The contours represent a major anticline marked by two elongated domes at the south and the southern end of a dome at the northern end. The southern domes represent the Rimutaka and Tararua ranges and the northern dome the Ruahine Range. The two saddles between these three ranges form the only road and railway routes between Wellington and the East Coast—the Rimutaka and Manawatu routes.

AGE OF SURFACES

Fossiliferous marine beds rest on the undermass only at Manawatu Gorge, the beds at this place having been described by Lillie and Fleming (1941, p. 3) as follows:—" The base of the series is marked by thick pebbly sandstones and conglomerates, often with calcareous concretions

yielding good Waitotaran fossils. On Whariti Road, resting on the greywacke erosion plane, there is a thick boulder bed, the boulders rounded and sub-angular, attaining diameters of 2 ft. and 3 ft. The middle part of the Te Aute Series is represented by muddy sandstones and overlain by one or more limestone bands. The pebbly and bouldery nature of a large part of the beds representing the Waitotaran, Nukumaruan and Castlecliffian stages on the Whariti and Saddle roads indicates marked emergence during these periods of part of the Ruahines north of the Gorge." It will be seen that a well-defined greywacke surface underlies the Tertiary beds at these places, and it is tempting to consider that this surface is the one represented by the summit height accordance. Further north-east on the Taupo-Napier Road Tertiary beds, slightly older than those in the Manawatu Gorge, rest on a greywacke surface near the crest of the Ruahine Range, and show that an upper Miocene erosion surface has been formed in this area also. Although there is good evidence for an erosion surface below these upper Tertiary sediments it is not impossible that the reconstructed surface passes over them and is younger. The best evidence for this is provided by the eastern side of the Tararua Range east of Eketahuna. At this place Ongley has mapped upper Tertiary beds extending along the valley of the Mangatainoka River for several miles in from the eastern flank of the Range. Although Ongley (1935, p. 5) states that the uppermost Tertiary beds (Mangahao Series) dip steeply along the eastern flank of the range, the reconstructed surface passes over this strongly deformed Tertiary strip without marked break. Such a relationship, if correct, can be explained only by assuming that the surface is younger than the orogeny that deformed these late Tertiary sediments. Such an explanation adds complexity to the late Tertiary history. The post-Tertiary orogeny has to be divided into two phases, an early but post-Mangahao phase responsible for the folding of the young Tertiary beds along the eastern side of the range and a later phase that elevated the mature land cut indifferently in both the Tertiary sediments and the undermass.

Although the contours have not been extended to cover the Wellington Peninsula, summit height accordance is well shown there when the Peninsula is viewed from the hills on the east side of the harbour. Summit height accordance is probably equally as good as in the ranges but the relief does not reach 2,000 ft. and the reconstructed surface cannot be clearly shown by the contours. The earliest erosion cycle marked by wide-open valleys in the Peninsula has been named the Kaukau cycle by Cotton (1912, p. 248). This cycle is marked by weathering that extends down for many feet in the "Greywacke" undermass and probably corresponds with the contoured surface that extends over the ranges to the east.

DRAINAGE AND CONTOURS

One of the most striking features of the area is the lack of a definite relation between the reconstructed surface and the directions of the present rivers. In north-west Nelson, in South Canterbury, and in most places where fossil peneplains have been resurrected the majority of streams flow down the slope of the surfaces at right angles to the contours. No such relationship exists in the Tararua Ranges. Instead the streams follow a trellised pattern apparently controlled by the

structure of the "greywacke" undermass. Such indifference to the contours can be most easily explained if the streams are antecedent to the latest uplift, and have become progressively more adjusted to the undermass for a considerable period of time, possibly extending back to pre-Castlecliffian times.

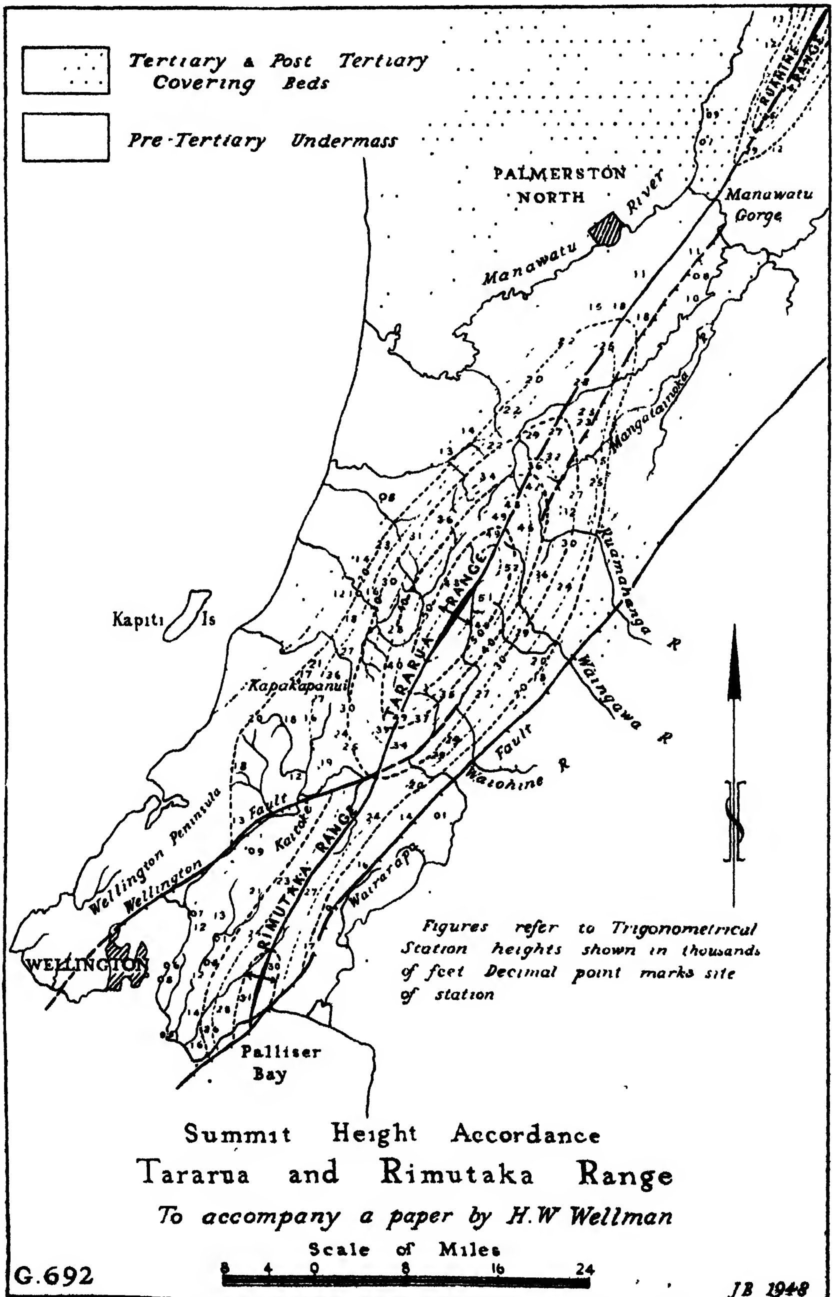

FIG. 1

RELATION BETWEEN SURFACE AND FAULTS

Cotton (1922) mapped the Wellington Fault scarp north-west of the Wellington Harbour. This fault is known to extend up the Hutt Valley and its further extension in a gentle curve to near Kaitoke has recently been established through the discovery of a recent fault scarp there by Hall (1946a). The writer knows of no reference to its further continuation, although the co-linear valleys of the Tauherenikau River and the Waiohine River lie on the extension of this fault line. Although not well shown on the 4 mile to the inch map, the fault-line-like pattern of these two streams is well brought out by the map published by the Tararua Tramping Club, the line of these valleys being marked by a track that follows over the low pass between them. The northern extension of this fault is less certain, but it may be significant that the southern flowing reaches of the Ruamahanga River, Waingawa River and the Mangatiriri River are all co-linear and connect the extension of the Wellington Fault with the main boundary fault mapped by Ongley (1935) on the east side of the Tararua Range south of the Manawatu River.

The southern half of the Rimutaka Range appears from the contours to be obliquely cut off by a major fault. The fault responsible is probably the same as that mapped by Ongley in 1943, as extending north in an almost straight line along the western side of Lake Wairarapa through Featherston and Woodside north almost to Eketahuna. Ongley's map shows no geology but only the recent trace of this fault. He mentions that earlier movements are certain and there is little doubt that the line represents an important tectonic feature that has been active at several periods in the past. It will be noticed that both the Wellington and Wairarapa faults are oblique to the axis of the ranges as defined by the contours, and that no apparent displacement of this axis has taken place along the line of the Wellington Fault.

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NOTE ON CALCITE SINTER TERRACES AND PISOLITES IN BLACKBALL COAL MINE

By MAXWELL GAGE, Canterbury University College, Christchurch

(*Received for publication, 30th November, 1948*)

CALCITE pisolites found in pools on limestone cave floors have been described as "cave-pearls". They may be seen in the State Coal Mine at Blackball, near Greymouth, where they form in drains and puddles in certain idle sections of the mine where water drips persistently. Smoothly rounded and of spheroid or ovoid shape, the pisolites are built of layers of calcite, each 0.5 to 1 mm. thick, and attain 20 mm. or more in diameter. The nucleus is generally a fragment of coal. The calcareous sinter forms rapidly on timbering, loose coal and other debris. Quite spectacular arrays of small stalactites are produced by permanent drips, and more copious flows give rise within a few weeks to miniature terraces on the floor.

These deposits are formed in an environment differing somewhat from that of a solution cavern in limestone. The source of calcite lies not in the coal measures (the Brunner formation—late Cretaceous or Eocene[1]), but in the directly overlying Island sandstone (middle Eocene), the grains of which are bound together by calcareous cement. In some places, however, the cement has been thoroughly leached, both coal measures and overlying sandstone being reduced to a free-running quartz sand, which is an excellent aquifer. This is one factor involved in the exceptional mobility of calcite, to which is ascribed the unusually rapid growth of sinter and pisolites in the mine. The other factor is the existence in the same seam at a higher level, but separated from the present mine by a coal-barrier, of old workings which are flooded and afford a great reservoir of CO_2-saturated water. Blackdamp is prevalent in the Blackball mines, and completely fills the old workings above water-level. Its abundance may safely be ascribed to attack upon the calcareous cement of the Island sandstone by sulphur acids derived from oxidation of widely-disseminated pyrite and marcasite nodules. The present mine is very wet, and it has been proved that water leaking from the old workings by way of the roof-aquifer is largely responsible for this condition. If there were some safe and easy method of draining the old workings, the task of the management of the present mine would be much simpler. Evidently the water from the old mine is capable of leaching further lime from the overlying rocks, and conveying it in bicarbonate solution to the new mine, where it is deposited in favourable situations free from oxidized sulphides. The part played by the sulphides is indicated by the prevalence in other parts of the present mine of water seepages that deposit alum salts and large quantities of ferric oxide, the latter being the end-product of oxidation of pyrite and marcasite.

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THE NEW ZEALAND

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Editor: N. A. Marris, M.Sc., B.Com. (Assistant Editor: M. O'Connor, M.Sc.) Department of Scientific and Industrial Research, Wellington

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THE LARVAL TRANSFER METHOD OF DETERMINING TOXICITY OF TIMBER PRESERVATIVES TO *ANOBIUM PUNCTATUM* DE GEER

By D. SPILLER and R. WINSOME DENNE*, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(*Received for publication, 20th September, 1948*)

Summary

An attempt was made to assess toxicity of timber preservatives by transferring partly grown *Anobium punctatum* larvae to treated blocks and recording survival after sixteen weeks. When it was found that larvae refused to ingest treated wood, the method was modified to allow for decrease in weight as a result of starvation. This refinement gave results convertible to ordinary mortalities with fair accuracy. When results obtained by larval transfer methods and modifications were compared with those obtained by egglaying techniques it was found that larval transfer methods over-estimated the amount of preservative required to give complete kill of larvae. It is concluded that larval transfer methods are unsuitable for the assessment of toxicity of timber preservatives. The techniques adopted throughout the work are described.

INTRODUCTION

FOR some years this Division has been investigating methods for the bioassay of timber preservatives. The common house borer *Anobium punctatum* De Geer has been selected as the test insect for insecticides because it causes more widespread damage than any other insect attacking timber in New Zealand. Of the testing methods available the one now employed is that in which female beetles lay eggs on small blocks of treated wood, the effectiveness of preservative being determined by survival or otherwise of larvae which hatch from these eggs. (Spiller 1948a). This method has several shortcomings, most important of which is that beetles are available only during the annual flight period of about five weeks. Further, the very small size of developing larvae makes examination of large numbers of test blocks impracticable until almost a year has elapsed.

With these limitations in view a method was evolved in which partly grown larvae were transferred to test blocks which were then stored under conditions suitable to larval growth. After a period the blocks were

* Now with the Shell Company of New Zealand Limited.

split and examined and records made of survival of larvae and of frass production. A similar method was employed by Cummins and Wilson (1936) with *Lyctus* larvae and by Becker (1938) Schulze and Becker (1942) and Kelsey (1946) with larvae of *Anobium punctatum*.

METHODS AND RESULTS

Testing Conditions.

All tests were carried out in a constant temperature room (22.5°C) and were of 16 weeks duration. The humidity was varied from test to test as indicated in Tables I and II.

Timbers and Test Blocks.

One inch cubes of straight-grained sap kahikatea (*Podocarpus dacrydioides* A. Rich) and pine (*Pinus radiata* D. Don) were used as test-blocks. All blocks for each test were sawn from the same board and randomised before treating. After treatment they were allowed to dry in the laboratory. They were then conditioned in the testing room for some weeks before use. To allow introduction of larvae the required number of $\frac{1}{16}$ in. holes was drilled and then countersunk in each block.

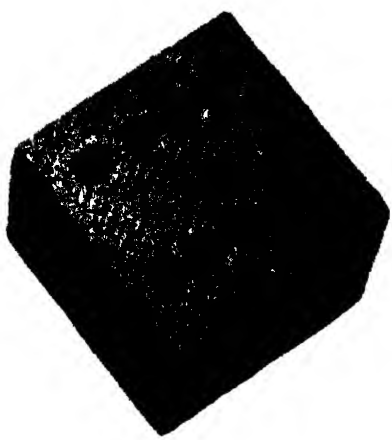

FIG. 1.—Typical Block Used with Larval Transfer Method of Determining Toxicity of Timber Preservatives to *A punctatum* (X 1 6). *(Photo A I. Hughes)*

Materials Tested.

Tests were made with zinc chloride, boric acid, zinc naphthenate, copper naphthenate, sodium pentachlorophenate, sodium fluoride, Wolman tanalith*, copper chloride, zinc sulphate, barium chloride and cadmium chloride.

* Wolman tanalith is a proprietary water soluble material comprising sodium fluoride 25 per cent.; disodium hydrogen arsenate 25 per cent.; sodium chromate 37.5 per cent.; dinitrophenol 12.5 per cent.

Block Impregnation.

If reproducible testing results are to be obtained the preservative must be uniformly distributed throughout test blocks, otherwise discordant data will arise due to greater survival of larvae in those portions of the block with lowest concentration. Satisfactory methods for most water soluble materials have been evolved (Spiller, 1948a), and these were used throughout. Adequate uniformity cannot be obtained with oil soluble preservatives because of reconcentration at the surface as the solvent evaporates, or with water soluble sodium pentachlorophenate because of sorption on the wood fibres.

Block Loadings.

The amount of preservative was established by chemical analysis of test blocks and is reported as percentage W/W on oven dry weight of wood.

Source and Handling of Larvae.

Larvae were obtained by splitting infested timber of many species and from many localities. Because of lack of uniformity in material it seemed desirable to condition all larvae by transferring them to white pine blocks and storing for about six months before use. Storage blocks were split as required, larvae removed and sorted or weighed as desired and then transferred to test blocks. To prevent injury, larvae were handled with two camel-hair brushes, never with forceps. Any larvae which were sluggish, abnormal or with suspected injury were discarded.

Design of Experiment.

Each test included a range of loadings to ascertain toxic level, a series of blocks at each loading to minimise variation and a fixed number of larvae in each block for assay. Experiments were recorded block by block and data massed under each loading. Details of number of blocks per loading and larvae per block are shown in the case of each experiment. For example B.5 ; L.6 indicates that there were five blocks each with six larvae.

Control Percentage.

Mortality in any particular treatment must be corrected for mortality in check blocks to obtain unbiased results. The appropriate method is that of Abbot (1925).

True mortality =

$$\frac{100}{1} \times \frac{\text{Mortality per cent. of Treatment} - \text{Check Mortality per cent.}}{100 - \text{Check Mortality per cent.}}$$

With the weight technique (see below) weight losses were corrected in the same way. In both cases true mortality or weight loss is recorded as " percentage control."

Establishment After Transfer.

Not all larvae establish after transfer to treated blocks. If this mortality were randomly distributed throughout the blocks it would be of no importance since it could be recorded and allowed for when the test was completed. If, however, this initial mortality were due to the different loadings of the material under test, it could not be ignored, nor could it be compensated for. The theoretical distribution

of survival in blocks is given by the binomial expansion. All transfer mortality data were tested for binomial randomness but no significant departures were found. Thus mortality may be corrected without introducing discrepancy due to concentration of preservative.

First Test Series.

In this set of experiments results were obtained by counting the number of larvae that survived in blocks treated with various preservatives and held under test for the required period. Mortalities were then calculated. Results are shown in Table I.

TABLE I. LARVAL MORTALITIES IN TEST BLOCKS AFTER PERIOD OF 16 WEEKS

Preservative and conditions of test.	Loading of preservative (per cent. W/W on oven dry wood)	Larvae transferred.	Larvae established.	Larvae recovered.	Percentage of larvae dead.	Percentage control.	Frass mg. per established larva.
Sodium pentachlorophenate; 75 per cent. R.H.; Kahikatea; B 7; L 16‡	1.8	112	98	58	40.8	23.3	9.6
	5.2	112	97	19	80.4	74.5	4.6
	9.2	112	107	26	75.7	68.4	–
	12.1	112	106	10	90.6	87.7	3.3
	15.0	112	102	17	83.3	78.3	3.5
	Check	112	101	78	22.8		21.1
Boric Acid; 70 per cent. R.H.; Kahikatea; B 6; L 8	0.32	48	Not recorded	26	45.8	33.3	10.7*
	0.53	48		31	35.4	20.6	9.8*
	0.82	48		14	70.8	64.1	4.0*
	1.47	48		2	95.8	94.8	1.8*
	2.85	48		1	97.9	97.4	0.9*
	Check	48		39	18.7	-	34.7*
Zinc chloride; 70 per cent. R.H.; Kahikatea; B 6; L 8	2.20	48	Not recorded	1	97.9	97.4	4.4*
	4.17	48		0	100.0	100.0	5.6*
	5.83	48		1	97.9	97.4	4.2*
	7.60	48		2	95.8	94.8	5.1*
	9.19	48		0	100.0	100.0	4.2*
	Check	48		39	18.7	-	34.7*
Zinc naphthenate; 70 per cent. R.H.; Kahikatea; B 12; L 8	0.17†	96	Not recorded	49	49.0	23.5	15.9*
	0.35†	96		45	53.1	29.7	14.7*
	0.65†	96		37	61.4	42.1	11.3*
	1.18†	96		10	89.6	84.4	2.7*
	1.96†	96		1	99.0	98.5	1.4*
	Check	96		64	33.3	-	20.2*
Copper naphthenate; 70 per cent. R.H.; Kahikatea; B 12; L 8	0.20†	96	Not recorded	16	83.3	75.0	6.0*
	0.43†	96		9	88.5	82.8	3.7*
	0.80†	96		4	95.8	93.7	2.8*
	1.48†	96		3	96.9	95.4	2.5*
	2.45†	96		1	99.0	98.5	2.0*
	Check	96		64	33.3	—	20.2*

† These loadings follow normal usage for naphthenates and are reported as percentage metal. Zn × 8.7 = Zinc naphthenate: Cu × 9.1 = Copper naphthenate.

* These figures based on number of transferred larvae.

‡ B 7; L 16 = Seven blocks each with 16 larvae.

Second Test Series.

During recording of treatments on sodium pentachlorophenate (Table I) it was apparent that surviving larvae from treated blocks were considerably smaller than when introduced into blocks and still smaller than larvae recovered from control blocks. Examination of frass from treated blocks showed that most of this consisted of chewings instead of faecal pellets while frass from check blocks was normal and consisted of pellets with only a small amount of chewings. To ascertain the extent of this change in frass composition a comparison was made of the number of faecal pellets present in samples taken from blocks with different loadings. A small standard glass measure was used to sample frass from each loading. These samples were evenly scattered on a small squared glass plate and the number of frass grains counted under a binocular microscope. Ten samples from each frass were used and their gross weights recorded. Results are expressed in numbers of faecal pellets per mg. of frass.

Sodium pentachlorophenate per cent.	15.0	12.1	5.2	1.8	Check
Pellets per mg. frass	32.5	39.8	120.8	248.8	155.0

Since the check sample consisted almost entirely of pellets these must have been larger than those from the 1.8 per cent. blocks which contained considerable chewings. This could only occur if check larvae were larger and confirms the observation that larvae recovered from treated blocks were smaller than those from check blocks. These results can be explained on the assumption that wood treated with sodium pentachlorophenate is repellent to larvae and that they can, at least in part, reject materials distasteful to them. However they do not cease tunnelling in the preservatized wood and frass production continues (*vide* Tables I and II). This rejection of treated wood implies near starvation for larvae but, more important, also implies insufficient consumption of preservative to produce a lethal effect during the test period.

An attempt was made to modify the technique of larval transfer and take into account the starvation which follows rejection. It is apparent that if a larva eats sufficient preservatized wood it will die and likewise, if there is continual refusal to ingest then the larvae will eventually die of starvation. With reference to this point Kelsey (1946) states " since the full value will only become apparent when larvae are compelled by starvation to eat treated wood " but there does not appear to be any evidence to show that starvation will compel the larvae to eat. During the period of starvation there must be a gradual reduction in larval weight as food reserves are used and if this loss is measured a suitable measure of starvation following rejection may be obtained.

The modified technique followed the original except that larvae were weighed. Larvae were sorted into weight ranges, randomized in groups of six or eight within each range, the group weight recorded and larvae then transferred to their block. Counts of number established in each block were made a few days later and the group weight corrected for those not establishing. At the end of the test period, test blocks were split and surviving larvae removed, counted and weighed. From this weight and the weight of larvae from check blocks a measure incorporating both mortality and extent of starvation was calculated as percentage loss of original weight of larvae established.

A prerequisite for this method is that group weights be randomly distributed within and between treatments. In each case group weights

were submitted to an analysis of variance but no significant departure from randomness was found.

The results obtained with this modification together with mortality data are shown in Table II.

TABLE II. LARVAL MORTALITY AND WEIGHT DECREMENT EXPERIMENTS

Preservative and conditions of test.	Larval weight range.	Loading of preservative (per cent. W/W on oven dry wood.)	Larvae transferred.	Larvae established.	Larvae recovered.	Per cent. dead	Per cent. control.	Weight of larvae. (mg.) Established.	Weight of larvae. (mg.) Recovered.	Average weight of larvae recovered. (mg.)	Per cent. loss.	Percentage control.	Frass. (mg. per established larvae.)
Zinc chloride; 68 per cent. R.H.; Kahikatea; B.5; L.6	4-6 mg.	0.51	30	22	14	36.4	5.2	104.3	54.8	4.2	47.5	29.5	9.1
		0.87	30	23	7	69.6	54.7	106.5	27.3	3.9	74.4	65.5	3.4
		1.25	30	28	7	75.0	62.7	132.4	21.2	3.0	84.0	78.5	2.6
		1.71	30	27	8	70.4	55.8	138.5	23.2	2.9	83.3	77.6	1.3
		2.41	30	26	4	84.6	77.0	142.7	10.3	2.6	92.8	90.3	1.1
		Check	90	73	49	32.9	—	340.2	253.4	5.2	25.5	—	15.9
ditto	6-10 mg.	0.45	30	25	19	24.0	1.2	176.0	122.2	6.4	30.6	8.8	14.1
		0.87	30	28	15	46.4	30.3	204.1	80.9	5.4	60.4	48.0	6.9
		1.21	30	25	9	64.0	53.2	191.3	43.9	4.9	77.0	69.8	3.5
		1.76	30	29	16	44.8	28.2	219.2	66.8	4.5	69.6	60.0	4.1
		2.31	30	27	9	66.6	56.6	195.2	33.4	3.7	82.9	77.5	2.2
		Check	84	65	50	23.1	—	357.6	272.2	6.6	23.9	—	20.3
Sodium fluoride; 68 per cent. R.H.; Kahikatea; B.5; L.6	4-6 mg.	0.45	30	26	3	88.5	82.9	122.7	5.8	1.5	95.3	93.7	1.0
		0.87	30	29	2	93.1	89.7	131.1	3.6	1.8	97.3	96.4	0.5
		1.23	30	27	2	92.6	89.0	122.0	3.9	2.0	96.8	95.7	0.6
		1.75	30	27	2	92.6	89.0	123.1	4.1	2.1	96.7	95.6	0.7
		2.36	30	24	0	100.0	100.0	141.0	—	—	100.0	100.0	0.7
		Check	90	73	49	32.9	—	340.2	253.4	5.2	25.5	—	15.9
Wolman tanalith; 68 per cent. R.H.; Kahikatea; B.5; L.6	4-6 mg.	0.45	30	26	3	88.5	82.9	123.8	5.0	1.7	96.0	94.6	1.6
		0.87	30	25	1	96.0	94.0	120.5	2.6	2.6	97.8	97.0	0.9
		1.23	30	22	4	81.8	72.9	106.3	10.2	2.6	90.3	87.0	0.6
		1.74	30	29	2	93.1	89.7	144.1	4.5	2.3	96.9	95.8	0.7
		2.36	30	26	0	100.0	100.0	125.6	—	—	100.0	100.0	0.7
		Check	90	73	49	32.9	—	340.1	253.4	5.2	25.5	—	15.9

Zinc chloride	4-7 mg.	0.39	24	24	21	12.5	Nil	133.0	112.7	5.4	15.3	Nil	10.8
78 per cent.		0.74	24	23	11	52.2	37.5	123.6	51.2	4.7	58.6	48.8	6.0
R.H.		1.14	16	15	8	46.7	30.5	96.5	34.5	4.3	64.4	56.0	4.3
Pinus radiata		1.58	24	22	1	95.4	94.0	115.4	5.2	5.2	95.5	94.4	2.8
B.3 ; L.8		2.22	24	24	2	91.7	89.2	129.2	7.1	3.6	94.5	93.2	3.4
		2.80	24	22	1	95.4	94.0	116.0	4.1	4.1	96.5	95.7	1.8
		Check	96	86	66	23.5	—	467.5	378.3	5.7	19.1	—	14.4
Zinc chloride	4-7 mg.	0.46	24	19	7	63.2	42.5	105.0	34.8	5.0	66.9	50.0	9.3
78 per cent.		0.83	24	23	5	78.3	66.1	124.1	20.9	4.2	83.2	74.7	5.0
R.H.		1.16	24	24	2	91.7	87.0	127.4	7.3	3.7	94.3	91.4	3.3
Kahikatea		1.19	24	23	2	91.3	86.4	116.9	7.3	3.7	93.8	90.7	5.2
B.3 ; L.8		2.18	24	22	2	90.9	85.8	117.5	6.0	3.0	94.9	92.3	2.8
		2.97	24	22	0	100.0	100.0	123.9	—	—	100.0	100.0	3.6
		Check	96	86	55	36.0	-	465.8	308.6	5.6	33.7	—	13.1
*Copper chloride	6-10 mg.	0.51	30	27	8	70.4	61.5	182.3	21.9	2.7	88.0	84.2	2.5
		2.62	30	25	11	56.0	42.8	186.8	26.9	2.4	85.6	81.1	3.9
*Zinc sulphate	6-10 mg.	0.42	30	30	20	33.3	13.3	203.4	101.4	5.1	50.1	34.4	13.3
		2.62	30	27	7	74.1	66.3	197.9	25.6	3.7	87.1	83.0	3.7
*Barium chloride	6-10 mg.	0.62	30	25	16	36.0	16.8	184.5	77.9	4.9	57.8	44.5	6.0
		3.06	30	28	4	85.7	81.4	208.0	14.1	3.5	93.2	91.0	1.1
*Cadmium chloride	6-10 mg.	0.61	30	26	2	92.3	90.0	187.7	7.6	3.8	96.0	94.7	0.9
		2.60	30	23	1	95.7	94.4	171.4	2.7	2.7	98.4	97.9	1.1
Check	6-10 mg.	Check	84	65	50	23.1	—	357.6	272.2	6.6	23.9	—	20.3

* All—68 per cent. R.H.
Kahikatea
B.5 ; L.6

DISCUSSION

The weight decrement technique was designed to measure toxicity as mortality plus loss in weight of surviving larvae. Were it not for this loss in weight through starvation following rejection of treated wood, the weight modified technique would give results similar to the original larval transfer method since weighing or counting would then be comparable. That there is not this equality is shown by Fig. 2 where "percentage control" obtained from mortality counts is plotted against "percentage control" obtained by weight modification for the seven preservatives and the thirty-nine concentrations reported in Table II. While normal mortality technique is shown to underestimate efficacy of materials as computed by weight decrement it is also apparent that the two methods are closely correlated. There is necessarily equality when 100 per cent. mortality is reached since this infers 100 per cent. loss in weight and vice versa. Likewise there are certain restrictions which tend to produce equality when mortality is low since it would be impossible to have death without a corresponding loss in weight. The converse does not apply and loss in weight can occur without deaths in the population. Arbitary curves were fitted to the data and satisfactory fits were obtained in several cases. The one shown is the simplest: $Y = 0.01X^2$ where Y = "control percentage" as measured by deaths and X = "control percentage" as measured by weight decrement. From this equation Y can be estimated from X with reasonable accuracy; the average variation of Y found from Y estimated being $\pm$ 4.4. From this equivalence of results it follows that even if the refinements of the weight decrement technique could be shown to give results nearer the true toxic level than the mortality technique there is no advantage in using weight decrement instead of the simpler mortality technique since results of either are convertible one to the other with reasonable accuracy.

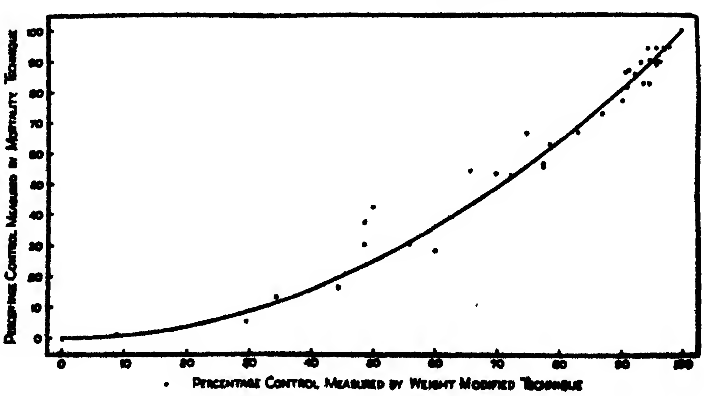

FIG. 2.—Relationship Between "Percentage Control" Obtained by Larval Transfer Mortality Technique and the Weight Modified Technique. The line has the Formulae $Y = 0.01X^2$. Data from Table II.

The curvature of the regression line in Fig. 2 implies a considerable loss in weight of surviving larvae. These weights have been tabulated in Table II and show that the average weight of recovered larvae tends to decrease as loadings increase. Sodium fluoride, Wolman tanalith and copper chloride are exceptions in that larval weights on these materials are similar at each loading.

Examination of the figures relating block loading to weight of frass per established larvae (Tables I and II) shows that frass production decreases as loadings increase, whenever loadings have been low enough to produce a graded mortality response. When this graded response was not produced as in the first experiment with zinc chloride (Table I) and with sodium fluoride and Wolman tanalith (Table II) no such relationship exists, the amounts of frass produced being small and substantially independent of loadings.

Schulze and Becker (1942) have used a mortality technique similar to that employed here and it seems desirable to comment on some results given in their paper. Their tests were carried out at 20°c. and 75 per cent. R.H. using test blocks of sap Scots pine which had been uniformly (sic) impregnated with preservative. Ten larvae ranging from about 0.6 mg. to 4-5 mg. more or less, were used for each test and no corrections were made for mortality of controls which did not exceed 10 per cent. on the average. These authors have shown that large *Anobium* larvae can starve for over a year and have recognized that some materials "scare the insects from eating, so that they die only from starvation." In spite of this they consider a testing time of either five or twelve weeks as sufficient since, "the true toxic level - - - is of practical importance only in the case of full impregnation of the wood."

Their results on size of larvae in relation to sensitivity to poison show that large larvae are more resistant than small and, very roughly the effect is that within the range 2 mg.-7 mg., mortality decreases about 10 per cent. for each milligram of increased weight. Likewise they have shown that results obtained with a four weeks test are different from those obtained when the test period is twelve weeks, the longer test showing the material to be more toxic.

Four "limiting values" have been taken by these authors for assessment of results, namely the 100 per cent. and 80 per cent. mortality points for both four and twelve weeks tests and it is insisted that these give a reliable estimate of toxicity of various materials.

If the 80 per cent. mortality level is accepted as a reliable estimate of the toxicity of the various materials in Tables I and II, and the values obtained in this way are compared firstly with the four and twelve weeks tests of Schulze and Becker (1942) and then with the toxicities of the same materials as determined by the egglaying technique (Spiller 1948 a, b, c, d) it is found that the larval transfer method consistently reports much higher toxic loadings than the egglaying technique. Further there is wide discrepancy between the four and twelve weeks tests as given by Schulze and Becker (1942) and results obtained with the sixteen weeks tests as reported in this paper (Tables I and II). Comparisons are given in Table III.

TABLE III. COMPARISON OF TOXIC LOADINGS* OBTAINED BY LARVAL TRANSFER AND EGGLAYING TECHNIQUES

Author.	Schulze and Becker.		This paper.		Spiller.
Period of test.	Four weeks.	Twelve weeks	Sixteen weeks.		Egglaying methods.
Technique.	Mortality of larvae		Mortality of larvae.	Weight decrement.	
Materials tested					
Boric acid	Not tested		1.47–0.82	Not tested	0.043–0.022
Sodium fluoride	> 6.2	0.6–0.36	<0.45	<0.45	0.19–0.12
Wolman tanalith	>5.6	0.78	<0.45	<0.45	0.06–0.042
Zinc chloride	45.0–28.4	28.4–18.2	<2.20	- -	0.18–0.11
			>2.41	1.71 2.41	
			>2.31	2.31	
			1.58–1.14	1.58–1.14	
			1.16–0.83	1.16 0.83	
Zinc sulphate	27.3 16.4	16.4–10.4	>2.62	2.62	0.9 0.53
Sodium arsenate	>15.2	>15.2	Not tested		⩽0.5
Copper sulphate	>46.7	<16.8	Not tested		⩽0.25
Barium chloride	>43.4	>43.4	3.06	<3.06	>1.0
Copper naphthenate	>17.5	<3.1	3.9†	-	Not tested
Zinc naphthenate	>22.8	2.8	10.3‡	- -	Not tested
Sodium pentachlorophenate	>14.5	>14.5	>15.0	-	1.2–0.5§

* W/W of oven dry wood. Schulze and Becker (1942) gave their figures as kilograms per cubic meter of wood. These values have been converted to loadings on the basis of a dry weight/green volume specific gravity of 0.422 for Scots pine. Because of this, figures are necessarily approximations to true loadings which are unknown.
† As copper naphthenate = 0.43 per cent. Copper.
‡ As zinc naphthenate = 1.18 per cent. Zinc.
§ Data unpublished.

In the light of these comparisons (Table III) it seems clear that it is necessary to consider carefully the value of data obtained by larval transfer methods. The hatching of larvae is the method of infestation that occurs in the field and it is considered that results obtained by the egglaying method are better estimates of the toxicity of a preservative than are those obtained by larval transfer. Further it is found that egglaying methods give a consistent and reproducible assay of toxicity in different years and on different timbers. Because of this it is considered that the results obtained by Schulze and Becker (1942), Kelsey (1946), and in this investigation do not give the true toxic values of the preservatives employed.

The reason for this failure of the larval transfer technique to indicate true toxicity is that *Anobium punctatum* larvae can in part reject treated wood. Because of this some do not acquire a lethal dose of preservative and remain alive even when the wood is heavily loaded with very toxic material, i.e. sodium fluoride and Wolman tanalith (Table II). Eventually they die of starvation. This selective ability of larvae constitutes a fundamental defect of larval transfer techniques and while it could be overcome by greatly extending the test period to say 12 months or more—the chief merit of the technique, namely speed of testing, would

disappear. That the test period would have to be extended to this extent is shown by results obtained by Schulze and Becker (1942) who report having kept *Anobium* larvae alive for up to 260 days without food. As a further point if it is assumed, as found by Schulze and Becker (1942) that susceptibility of larvae to poison decreases with increasing age, there can be no assumption that the toxic level assayed with part-grown larvae is the same as that required to control neonate larvae. Cummins and Wilson (1936) found a similar transfer method unsatisfactory for comparing toxicity of various materials to *Lyctus* larvae and stated "it appears essential if satisfactory comparisons of toxicity are to be obtained that the beetle test should be employed, although this method requires more time and can only be carried out during a restricted period of the year." The authors are in agreement with this opinion.

CONCLUSION

Larval transfer techniques are unsuitable for the assessment of toxicity of timber preservatives.

ACKNOWLEDGMENT

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TOXICITY OF WOLMAN TANALITH TO THE COMMON HOUSE BORER, *ANOBIUM PUNCTATUM* DE GEER

By D. SPILLER, Plant Diseases Division, Department of Scientific and Industrial Research

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Summary

Tests have shown that Wolman Tanalith loadings equal to 0.06 per cent. of the dry weight of treated wood prevents development of larvæ of *Anobium punctatum*. At loadings of 0.042 per cent. and below larvæ were able to survive.

WOLMAN TANALITH is a proprietary water-soluble wood preservative comprising a mixture of sodium fluoride 25 per cent., disodium hydrogen arsenate 25 per cent., sodium chromate 37.5 per cent. and dinitrophenol 12.5 per cent. The various Tanalith materials have been used in other countries for treating timber to prevent both fungal decay and attack by termites. At present, Tanalith is the only water-soluble preservative employed in New Zealand for pressure impregnation of building timbers to prevent attack by insects, especially the common house borer *Anobium punctatum* De Geer.

The manufacturers of Wolman salts recommend a minimum dry-salt retention of 0.35 pounds per cubic foot of wood, which is equivalent to a dry-salt retention of 2.9 pounds per 100 super feet. This figure is based on their overseas experience and it is important to know if such a figure will be sufficient to prevent insect attack under the different conditions pertaining in this country. It is of equal importance to know if the amount recommended is in excess of that required to protect timber from attack.

Kelsey (1946) published a preliminary report on the toxicity of Tanalith to *Anobium punctatum,* using wood of *Pinus radiata* D. Don. impregnated under "commercial" conditions. He considered that a Tanalith concentration of 0.25 pounds per cubic foot of wood (2.08 pounds per 100 super feet) would be ample to prevent establishment of *Anobium punctatum* in *Pinus radiata* and recommended that *Pinus* be treated to give complete penetration and a minimum retention of Tanalith dry salt of 0.25 pounds per cubic foot of wood.

Harrow (to be published) has shown that complete penetration of *Pinus* is readily obtained with several pressure impregnation schedules. When these schedules are adopted by commercial treating plants, more information will be needed about the amounts of Tanalith required to prevent establishment of *Anobium* infestations. Tests of toxicity of Tanalith have now been completed. The methods employed were identical with those described in a previous paper (Spiller, 1949). In all, 99 treated blocks were tested and these covered loadings of Tanalith ranging from 0.003 to 1.8 per cent. The test timbers were sapwood kahikatea (*Podocarpus dacrydioides* A. Rich.) and sapwood pine (*Pinus radiata* D. Don.); six boards (1, 2, A, B, C, D) of the former and two (E, H) of the latter.

Results are shown in Table I.

TABLE I. TOXICITY OF WOLMAN TANALITH TO LARVAL *Anobium punctatum*

Year Tested.	Wood Species.	Board.	Loading Results	(Per cent. W/W of Oven Dry Weight of Block) (o Blocks With Live Larvae Absent) (+ Blocks With Live Larvae Present)						A†	B‡
1945-46	Kahikatea (*Podocarpus dacrydioides*)	1	Loading per cent	1.8	0.9	0.45				0.045	—
			Result	o o	o o	o o					
		2	Loading per cent	1.5	1.2	0.5	0.16			0.16	—
			Result	oooo	o o	ooooo ooooo	ooo				
1946-47		A	Loading per cent	0.49	0.25	0.10	0.062	0.021	0.005	0.062	0.021
			Result	o o	o o	o o	o o	+ +	+ +		
		B	Loading per cent.	0.53	0.27	0.10	0.059*	0.021	0.005	0.010	0.59
			Result	o o	o o	o o	+ +	+ +	+ +		
		C	Loading per cent.	0.53	0.25	0.11	0.061	0.021	0.005	0.061	0.021
			Result	o o	o o	o o	o o	+ +	+ +		
		D	Loading per cent.	0.39	0.18	0.078	0.045	0.016	0.004	0.045	0.016
			Result	o o	o o	o o	o o	+ +	+ +		
	Pine (*Pinus radiata*)	E	Loading per cent.	0.28	0.20	0.10	0.060	0.020	0.005	0.060	0.020
			Result	o o	o o	o o	o o	+ +	+ +		
		H	Loading per cent.	0.39	0.17	0.067	0.042	0.014	0.003	0.067	0.042
			Result	o o	o o	o o	+ o	+ +	+ +		

* Two small larvae in each block

† The lowest loading at which no live larvae were present in test blocks.

‡ The highest loading at which live larvae were present in test blocks.

DISCUSSION

These results show that Tanalith is very toxic to *Anobium* larvæ. All loadings of 0.06 per cent. and higher gave a complete kill while loadings of 0.042 per cent. and below were insufficient to prevent development of larvæ. Between these limits the data is not consistent for, while in board B a loading of 0.059 per cent. permitted the survival of two small larvæ in each block, in board D no larvæ survived at a loading of 0.045 per cent. This inconsistency is of little importance because loadings as low as these will not be employed in commercial treatments as a safety factor is necessary to guard against faulty plant operation and variations in wood density. As a loading of 0.06 per cent. is equal to a net dry-salt retention of about 0.14 pounds per hundred super feet it is apparent that the present net dry-salt retention of 2.9 pounds per hundred super feet is unnecessarily high and should be reduced. If the retention were reduced to 0.8 pounds per hundred super feet and this amount evenly distributed throughout the wood—and the adoption of efficient treating schedules will ensure this– the safety factor would still be × 5.7 and more than sufficient to cope with any chance variation in wood density or in plant operation. Lowering the salt retention from 2.9 pounds to 0.8 pounds per hundred super feet would not lessen the effectiveness of treatment, but savings in salt costs would amount to 3.5 shillings per hundred super feet treated.

Further studies on toxicity, permanence and the size of the safety factor required may show that the net dry salt retention can be further reduced and a correspondingly greater saving effected.

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TOXICITY OF PENTACHLOROPHENOL TO THE COMMON HOUSE BORER *ANOBIUM PUNCTATUM* DE GEER

1. RESIDUAL CONTACT AND OVICIDAL ACTION

By D. SPILLER, Plant Diseases Division, Department of Scientific and Industrial Research

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Summary

This paper, after reviewing the literature on insecticidal activity of pentachlorophenol, discusses the importance of residual contact insecticides for control of infestations of the common house borer, *Anobium punctatum* De Geer. The techniques of testing, block treating and of measurement are given in detail. It was found that pentachlorophenol acted as a residual contact insecticide, an average of 0.18 eggs per female being laid on blocks treated with 2.2 per cent. pentachlorophenol compared with 8.2 eggs per female on untreated blocks. Further, of the eggs laid on treated blocks only 23.3 per cent. hatched compared with 93.4 per cent. hatching on untreated blocks. These two factors gave a control equivalent to killing 99.4 per cent. of potential eggs.

Spiller—Toxicity of Pentachlorophenol to the Common House Borer, *Anobium punctatum* de Geer

Repetition of the experiments after treated blocks had aged for one and two years showed that while these effects do not appear to be permanent they are sufficiently lasting to warrant the extensive use of pentachlorophenol for control of existing infestations.

Pentachlorophenol was first used as a fungicide. It has since been widely used for preventing fungous decay of timber in houses and timber in contact with the ground. From this use pentachlorophenol has gradually been adopted as a general timber preservative and is now recommended for prevention and control of both fungous and insect attack.

There are few references to the effectiveness of pentachlorophenol for preventing insect attack of seasoned timber and only scattered attempts have been made to assess its value for this purpose. Most tests have been made against termites, but results from such tests may not apply to timber insects proper (*Anobium; Lyctus*) because of biological differences of the two groups.

The insecticidal properties of pentachlorophenol have been noted by several investigators. Tattersfield, Gimingham and Morris (1925) found that as a spray in benzene solution, concentrations above 0.1 per cent. showed toxicity as a contact poison against *Aphis rumicis.* Ginsburg and Granett (1935) by feeding larvæ of silk moth (*Bombyx mori*) on mulberry leaves sprayed with various dilutions of pentachlorophenol, found that concentrations of 0.10 per cent. gave a complete kill in two days and that the lowest dilution tested (0.025 per cent.) was appreciably toxic. Bushlands (1940) found that 0.67 per cent. of pentachlorophenol gave complete control of young screw worm larvæ (*Cochliomyia americana*). Pentachlorophenol was also found to be toxic to young codling moth larvæ (Smith, Siegler and Munger, 1938). In addition it has shown pronounced toxicity against termites (Wolcott, 1945). Kelsey (1946) has shown that *Anobium* females did not oviposit on blocks that had been treated with 5 per cent. pentachlorophenol solutions. Weinman and Decker (1947) reported that pentachlorophenol was toxic to black carpet beetle (*Attagenus piceus*), the toxicity being retained for more than eighteen months after treatment. The West Indian dry-wood termite (*Cryptotermes brevis*) was used by Wolcott (1947) to measure permanence of termite repellents. He found that wood dipped in a 1.0 per cent. solution of pentachlorophenol resisted attack for 337 days and that specimens dipped in 2 and 5 per cent. solutions were still unattacked after 33 months.

Large amounts of pentachlorophenol are used each year in New Zealand by commercial concerns specializing in treating infestations of common timber insects. Repeated reports of satisfactory control of *Anobium* infestations after surface spraying with pentachlorophenol solutions suggested that pentachlorophenol may act as a residual contact poison and indicated the need of investigating the effectiveness of this material.

Preliminary experiments confirmed the suggestion that pentachlorophenol acted as a residual contact insecticide and showed that it was capable of killing *Anobium* beetles after a few hours of contact.

Residual contact insecticides have an important place in the control of existing infestations of *Anobium.* In a house so much timber is inaccessible that no surface treatment can kill all larvæ present. If however, a residual contact insecticide is sprayed on to these surfaces, beetles

will be killed soon after they emerge and before eggs are laid. Because development of *Anobium* from egg to adult takes at least three years, the recognised contact insecticides (e.g. D.D.T.) may not be suitable for this purpose as their residual films lose effectiveness within a few weeks or months of application. With such insecticides it would be necessary to spray prior to the flight in each year, making the cost prohibitive. If, however, a residual contact insecticide, effective for at least three years could be found, then economic control of infestations would be assured.

This investigation of pentachlorophenol had as its purpose the measurement of contact effects and permanence, as these relate to the problem of *Anobium* control. The methods of obtaining known doses of pentachlorophenol are not identical with commercial operations, but it is considered that the doses listed here approximate the doses that would occur with solutions of similar concentration used under field conditions. The exact relationship will be investigated in further experiments.

TECHNIQUE

Biological Methods

The single female technique and Type IV cages as described by Spiller (1948) were used throughout this investigation. Methods of collecting, sexing and handling the *Anobium* beetles were identical with those described in the above paper. Standard methods were used for egg counting and for assessing egg hatching, the criterion of hatching being presence of frass within the egg capsule. Each test was carried out at 22.5°C. and at constant humidity. The humidity, however, was changed from year to year as knowledge of optimum conditions accumulated.

MEASUREMENT METHODS

Measurement of Residual Contact Effects

It has been usual practice to measure the efficiency of insecticidal films in terms of mortality of the test insect. Sometimes this mortality has been recorded at the end of a stated period and while insects were still dying, but in other cases mortality has been recorded after it became stationary. In these experiments toxicity was measured by the numbers of eggs laid before females were killed by contact action. This method simulates field practice and consequently presents no difficulties of interpretation. Such difficulties do occur with mortality counts and statements such as "66 per cent. dead in 24 hours" are almost impossible to interpret in terms of field usage.

Measurement of Ovicidal Effects

The ovicidal effect was measured by counting the numbers of eggs which had hatched and comparing this number with the total eggs laid.

Measurement of Potency-dosage Effects

The relationships between dosage of pentachlorophenol and the control at each dosage is of great importance. This relationship was measured by taking the following series of dosages 0.25 per cent., 0.6 per cent., 1.0 per cent., 1.5 per cent., 2.2 per cent., and measuring the residual contact and ovicidal effect at each dosage level.

Measurement of Permanence

Permanence was assessed by treating all blocks at one time and using the same blocks in successive years. The blocks were thus aged for a few weeks, a year and two years before being used to measure the above effects.

METHODS OF TREATING BLOCKS

The blocks used in these experiments had average dimensions of 2.5 cm. x 2.5 cm. x 0.8 cm. The methods of cutting blocks were such that the 2.5 cm. x 2.5 cm. face, was the cross grain of the timber and the lesser dimension was along the grain. The use of end grain follows from the necessity of providing adequate egg laying sites. Eight boards were used:—Two pine (*Pinus radiata* D. Don); one rimu (*Dacrydium cupressinum* Sol.); two matai (*Podocarpus spicatus* R. Br.) and three kahikatea (*Podocarpus dacrydioides* Rich.). Blocks from these boards were kept as separate entities throughout treatment. From each board groups of twenty* blocks were taken at random and one of these groups allocated to each dosage level. In all, there were 65 different combinations of " wood-dosage " and 862 blocks.

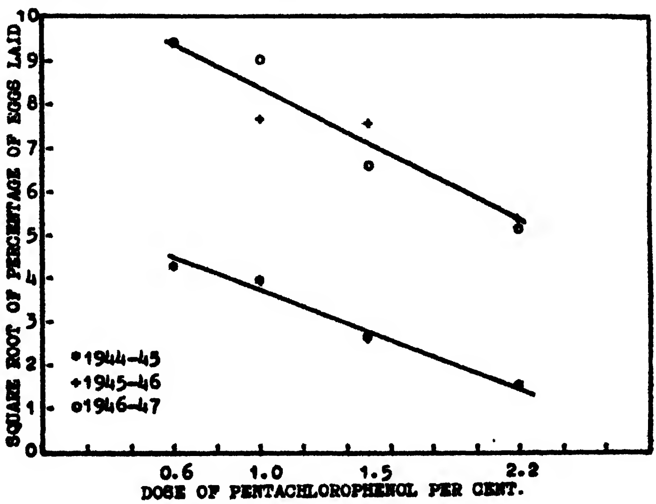

FIG. 1.—Relation between number of eggs laid (as square root of percentage of checks, Table IV) and dose of pentachlorophenol in each year.

Blocks were treated in the following standardized manner:—A group of blocks was placed in a 1000 ml. beaker. A wire gauze circle of the same diameter as the beaker was placed on top of the blocks and a lead weight placed on this gauze to prevent the blocks floating when the treating solution was run in. The beaker with the blocks was placed in a large desiccator and the unit evacuated with a Hyvac pump for 30 minutes. At the end of this period almost complete vacuum was established. Treating solution was now run into the beaker and after the required amount (usually 600 ml.) had been added, the vacuum was released and the desiccator opened.

Experiments have shown that under these conditions of treatment, the volume of liquid taken up by the blocks is substantially equal to the volume of the initial voids within the blocks and thus penetration is complete.

* Usually there were 20 blocks, in a few cases there were 14 or 15, while with board No. 4 and No. 7, 28 blocks were used at each dosage.

After the blocks had soaked for an hour they were removed from the beaker and placed on their narrow edge (0.8 cm.). This allowed the two egg-laying surfaces to dry equally. After drying blocks were stored in the humidity room until required for experiments. This procedure was repeated at each " wood-dosage " combination.

Treating solutions were made up separately for each treatment. No plasticiser was added. Concentrations are expressed as grams of pentachlorophenol to 100 ml. of solvent. These solutions were made up in a highly volatile solvent (petroleum ether 40°-70°c.) which, unlike the more conventional kerosene or mineral turpentine, left no residue likely to influence the insecticidal potency of the pentachlorophenol. As a check on absence of solvent toxicity, eight sets of blocks, one of each board, were treated with solvent alone and used as a comparison with untreated blocks. As no differences in egg laying or egg hatching were found, figures from these solvent treated blocks have been grouped with untreated blocks and termed checks in the tables below.

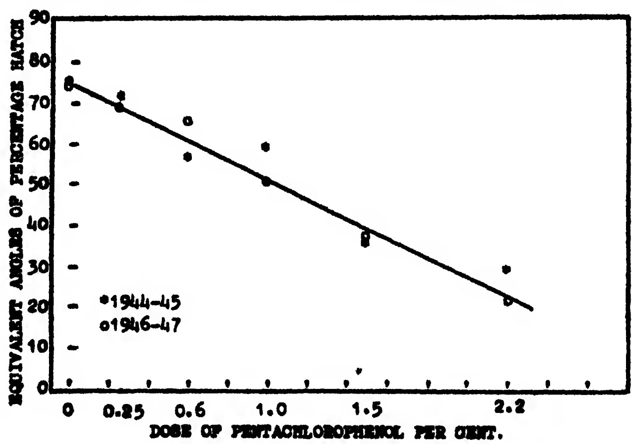

FIG. 2.—Relation between percentage of eggs hatching (as equivalent angles) and dose of pentachlorophenol for the 1944-45 and 1946-47 flight.

METHODS OF CO-ORDINATION OF RESULTS

Co-ordination of the results of the experiments reported in Tables I-VIII necessitates transformation of the percentages of eggs laid, of eggs hatching and " percentage control " to other scales approximately linear upon dosage or a function of dosage.

For egg-laying this linearity is achieved by transforming the percentage number of eggs laid to their square roots and plotting against dosage (Fig. 1).

For egg-hatching and control percentage approximate linearity is achieved by transforming percentages to equivalent angles and plotting against dosage (Fig. 2) or the logarithm of the dosage (Fig. 3).

A further co-ordination of results is effected by plotting " control percentage " values of the 1944-45 flight against percentages of similar dosages of the 1946-47 flight. A straight line results (Fig. 4).

In some cases the lowest dose (0.25 per cent.) has been excluded from these figures because it fails to conform with the general trend of results at higher dosages. Such observations are not uncommon in toxicity studies (Finney, 1947) and it now seems generally accepted

that rejection of results from lower dosages is a valid procedure, if in fact they do not follow the general trend of higher dosages and if interest is centered around the higher kills.

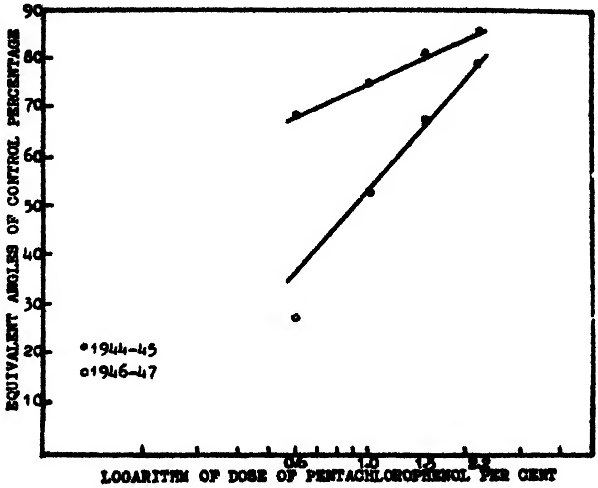

FIG. 3.—Relation between percentage control (as equivalent angles) and logarithm of dose of pentachlorophenol for the 1944-45 and 1946-47 flight.

The reasons for exclusion of the egg hatching results of the 1945-46 flight from Fig. 2 and control percentages of the same flight from Fig. 3 will be apparent after examination of results.

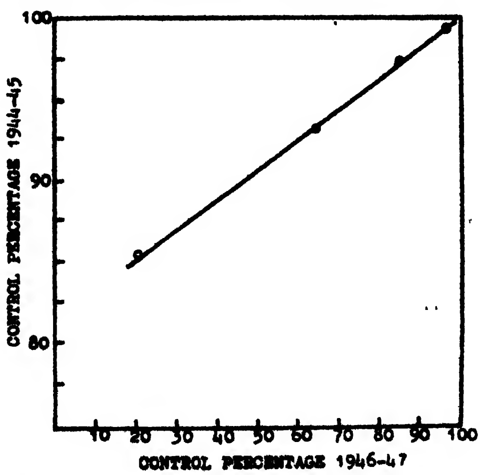

FIG. 4.—Relation between percentage control of the 1944-45 flight and percentage control from the same blocks two years later (1946-47 flight).

Most of the data in the tables were in a form suitable for examination by methods of analysis of variance. In some cases single classification has been employed, in others two way classification as woods and dosages. These analyses have not been computed on raw data but on

figures obtained after various transformations. Percentage hatchings were transformed to equivalent angles. Mean numbers of eggs laid were transformed to their square roots. The number of eggs laid by each female was used for analysis of the data on which Table II is based, after transforming the number laid per female to $\sqrt{n + \frac{1}{2}}$, which transformation has been recommended by Bartlett (1947) where the means are small and where zero values occur. The use of both transformations follows from the known root-normal distribution of *Anobium* egg-laying (Spiller, 1948). The data in Tables I and V have not been analysed because the very small numbers of eggs at the higher dosages introduce an instability into both the mean values for eggs laid and the hatching of these eggs. However, the significance of the data is obvious from inspection.

RESULTS

A. *Residual contact effect*

I. The 1944–1945 flight

In this year the experiment comprised five concentrations of pentachlorophenol (0.25 per cent., 0.6 per cent., 1.0 per cent., 1.5 per cent., 2.2 per cent.) an untreated and a solvent check with each board. Relative humidity was 75 per cent. Approximately a month after treatment, a randomly selected " female and male " were placed on each block. Three months later the number of eggs laid by each female and the number hatching on each block were recorded. The mean number of eggs per female is shown in Table I.

TABLE I. MEAN NUMBER OF EGGS PER FEMALE LAID AT EACH COMBINATION OF " WOOD-PENTACHLOROPHENOL DOSAGE " TOGETHER WITH THE WEIGHTED MEAN (1944-1945 FLIGHT)

Board Number.	Wood.	Dosage of Pentachlorophenol (Per Cent.)					
		Check	0.25	0.6	1.0	1.5	2.2
1	Pinus	4.9	9.1	1.3	1.2	1.2	0.05
2	Pinus	7.2	6.5	0.2	0.1	0.5	0.1
3	Rimu	15.9	1.1	0.7	0.2	0.1	0.1
4	Matai	6.1	3.2	4.8	0.9	1.2	0.5
5	Matai	8.2	6.1	0.1	0.0	0.2	0.1
6	Kahikatea	7.4	6.2	2.1	2.4	0.5	0.05
7	Kahikatea	6.9	5.8	0.8	0.4	0.4	0.2
8	Kahikatea	15.7	8.0	0.1	0.1	0.0	0.3
Weighed mean		8.2	5.8	1.43	0.66	0.53	0.18

The decrease in number of eggs as the dosage increases is obvious.

II. The 1945–1946 flight.

The blocks of board No. 7 (Table I) were again used for this year to confirm the residual contact effect and to measure loss in potency. Twenty-eight blocks were used. Other methods were identical with those

of the previous flight except that the humidity of testing was 80 per cent. The mean number ot eggs laid per female at each dosage is shown in Table II.

TABLE II. MEAN NUMBER OF EGGS PER FEMALE LAID AT EACH DOSAGE TOGETHER WITH THE DATA REQUIRED FOR TESTS OF SIGNIFICANCE. TESTS OF SIGNIFICANCE MUST BE PERFORMED ON THE TRANSFORMED DATE. (1945-1946 FLIGHT)

Dosage of Pentachlorophenol (Per cent)	Check	0.25	0.6	1.0	1.5	2 2
Mean number of eggs per female	6.2	8.4	10.4	3.6	3.5	1.7
Mean of $\sqrt{n+\frac{1}{2}}$ of number of eggs per female	2.1	2.4	2.7	1.5	1.5	1.2
Standard error of the mean of $\sqrt{n+\frac{1}{2}}$	0.29	--	--		--	—
Least differences for significance at 5 per cent level	0.81	--	--	--	--	—

The differences between the doses are highly significant. The details for tests of significance are included in Table II.

III. The 1946–1947 flight.

Seven of the eight sets of blocks used in 1944-45 (Table I) were used for this year. Over two years had elapsed since these blocks were treated and any loss in potency with time, should have been apparent. Somewhat unsatisfactory results were obtained in the previous year and as this was considered due to insufficient replication, a reversion was made to larger numbers—a technique which had given satisfactory results in the first year. In all 598 females and blocks were used. The humidity of the testing room was 86 per cent.

The mean number of eggs per female at each combination of " wood-dosage " is given in Table III.

TABLE III MEAN NUMBER OF EGGS PER FEMALE LAID AT EACH COMBINATION OF " WOOD-PENTACHLOROPHENOL DOSAGE " TOGETHER WITH THE WEIGHTED MEANS (1946-1947 FLIGHT)

Number.	Wood	Dosage of Pentachlorophenol (Per cent)						Weighted mean.
		Check	0.25	0.6	1.0	1.5	2.2	
1	Pinus	21.3	26.3	18.8	16.0	9.7	2.4	15.7
3	Rimu	28.8	16.5	23.6	9.8	1.1	1.5	13.5
4	Matai	16.4	16.3	15.6	22.3	8.3	10.6	14.9
5	Matai	34.1	24.5	16.4	25.8	25.2	15.7	23.6
6	Kahikatea	18.7	14.0	26.6	6.1	1.9	1.5	11.0
7A	Kahikatea	17.1	16.5	19.4	31.0	15.2	5.2	17.5
7B	Kahikatea	19.7	14.1	29.6	11.2	7.4	4.5	12.6
8	Kahikatea	19.6	22.2	13.8	13.4	3.7	1.7	12.7
Weighted mean		22.0	19.0	19.7	17.8	9.4	5.8	

The differences between woods are not significant; the differences between dosages are highly significant. The means of the square roots of the means are shown in Table IIIA, together with the standard error of this mean and the least difference required for significance at the 5 per cent. level.

TABLE IIIA. DATA REQUIRED FOR TESTS OF SIGNIFICANCE BETWEEN NUMBER OF EGGS LAID AT EACH DOSAGE OF PENTACHLOROPHENOL AS GIVEN IN TABLE III. THE TESTS OF SIGNIFICANCE MUST BE MADE IN THE TRANSFORMED DATA

Dosage of Pentachlorophenol (Per cent.)	Check	0.25	0.6	1.0	1.5	2.2
Mean of square root of mean number of eggs per female	4.6	4.3	4.5	4.0	2.7	2.1
Standard error of mean	0.28					
Least differences for significance between any two means (5 Per cent.)	0.81					

In Table IV the number of eggs laid in each year has been shown as a percentage of the check of that year. In this way allowance is made for year to year variation in numbers of eggs laid, thus facilitating comparison between different experiments.

TABLE IV. MEAN NUMBER OF EGGS PER FEMALE AT EACH PENTACHLOROPHENOL DOSAGE IN EACH YEAR EXPRESSED AS A PERCENTAGE OF THE MEAN NUMBER OF EGGS LAID ON CHECK BLOCKS OF THAT YEAR

Flight year.	Pentachlorophenol Dosage Per cent					
	Check	0.25	0.6	1.0	1.5	2.2
1944-45	100	70.7	17.4	8.1	6.5	2.2
1945-46	100	100	100	58.1	56.5	27.4
1946-47	100	86.4	89.5	80.9	42.7	26.3

B. Ovicidal effect

In addition to acting as a residual contact insecticide, pentachlorophenol has an ovicidal effect. This was measured by counting the number of hatched eggs on each block, grouping their values for each " wood-dosage " combination and then converting these to a percentage hatching of total eggs on these blocks. The grouped data from the 1944-45 flight are shown in Table V. These percentage hatchings are also shown as equivalent angles in Table V and these angles are plotted against dosages in Fig. 2.

TABLE V. NUMBER OF EGGS LAID AND PERCENTAGE HATCHING OF THESE EGGS AT DIFFERENT DOSAGES OF PENTACHLOROPHENOL (1944-1945 FLIGHT). THE EQUIVALENT ANGLES OF PERCENTAGE HATCHING ARE ALSO SHOWN

Dosage of Pentachlorophenol (Per cent.)	Check	0.25	0.6	1.0	1.5	2.2
Number of eggs laid	2392	938	242	110	88	30
Percentage hatching	93.4	89.8	69.1	73.4	35.5	23.3
Equivalent angles of percentage hatching	75.1°	71.4°	56.2°	58.9°	36.6°	28.9°

The hatching percentages of the following year (1945–46) are given in Table VI.

TABLE VI. NUMBER OF EGGS LAID AND PERCENTAGE HATCHING AT EACH DOSAGE OF PENTACHLOROPHENOL (1945-1946 FLIGHT)

Dosage of Pentachlorophenol (Per cent.)	Check	0.25	0.6	1.0	1.5	2.2
Number of eggs laid	174	233	291	102	99	48
Percentage hatching	89.7	96.2	91.4	95.1	69.5	72.9

These differences are not significant. No suggestion is available as to why such results should arise in this year.

The hatching percentages of the 1946–47 flight are given in Table VII.

TABLE VII NUMBER OF EGGS LAID AND PERCENTAGE HATCHING OF THESE EGGS AT DIFFERENT DOSAGES OF PENTACHLOROPHENOL (1946-1947 FLIGHT) THE EQUIVALENT ANGLES OF PERCENTAGE HATCHING ARE ALSO SHOWN

Dosage of Pentachlorophenol (Per cent)	Check	0.25	0.6	1.0	1.5	2.2
Number of eggs laid	2178	1733	1893	1890	935	613
Percentage hatching	91.2	86.7	81.2	59.8	32.1	11.6
Mean equivalent angle	74.9°	68.3°	65.4°	50.6°	37.5°	21.3°
Standard error of angular mean	2.92°	—	—	—	—	—
Least Difference required for significance at 5 per cent level	8.4°	—	—	—	—	—

There were no significant differences in the hatchings on different woods, but the differences between dosages are highly significant. The angular values are plotted in Fig. 2 together with the similar values of the 1944-45 flight.

C. Percentage control

In the results given above (Tables I-VII) two effects have been considered: the action of pentachlorophenol as a residual contact insecticide and its ovicidal action. It is desirable to merge these two effects into a single figure which measures the overall control afforded by a particular dosage. This is achieved when the figures in Table IV are multiplied by the hatchings as given in Tables V, VI, and VII after the latter have been corrected for check mortality. This correction is normal procedure, the appropriate formula being that given by Abbott (1925). The figures arrived at in this way are termed "percentage control" in this paper. It is a measure of the number of viable eggs which occur at a particular dosage when 100 viable eggs appear on the check blocks. The values for the three years are given in Table VIII.

TABLE VIII. PERCENTAGE CONTROL AT EACH DOSAGE OF PENTACHLOROPHENOL IN EACH YEAR

Dosage of Pentachlorophenol (Per cent.)	0.25	0.6	1.0	1.5	2.2
1944-45 Per cent. control	30.9	86.2	93.5	97.5	99.4
1945-46 Per cent. control	11.3	0.0	61.7	68.9	85.3
1946-47 Per cent. control	18.5	21.0	64.6	85.2	96.7

These values for the years 1944-45 and 1946-47 are plotted against each other in Fig. 4. The values for the 1945-46 flight period have been excluded because of the anomalous hatching values in that year.

DISCUSSION

Three factors are important in any discussion of the value of pentachlorophenol for control of *Anobium* infestations: residual contact effect, ovicidal effect and permanence. From the data in Tables I-VIII there can be no doubt that pentachlorophenol has a residual contact effect and that it is also ovicidal. This fortunate combination of separate effects results in excellent control being achieved (Table VIII) with dosages of a few per cent. However, Figs. 1, 3 and 4 each indicate that pentachlorophenol cannot be regarded as permanent in the sense of lasting indefinitely. Fig. 1 shows that many less eggs were laid at each dose during the 1944-45 flight than in subsequent flights. From Fig. 3 it appears that the " percentage control " of the 1944-45 experiment was much greater than that of the 1946-47 flight, while Fig. 4 shows that loss in control during the test period is linearly related to control at the commencement of test and indicates that a dosage with initial control of 82 per cent. would give no control two years later. From Fig. 4 it could be argued that, if 100 per cent. control were achieved with the initial dose, then no loss in control would result within the next two years and this argument could be repeated for succeeding periods and would lead to an assumption of permanence when a certain dosage is applied in the first instance. Such argument is specious, but does not conform to the data of Fig. 4 in which it is shown that loss in toxicity is proportional to the original potency.

Fig. 4 suggests that loss in potency is proportional to the quantity of pentachlorophenol used in the initial treatment. Such a loss could be explained by volatilisation of pentachlorophenol. The vapour pressure of pentachlorophenol is very low at normal temperatures (0.00011 mm. mercury at 20°c., Hatfield, 1945), but nevertheless may cause appreciable loss of material within two years. Evaporation is not the only mechanism which can account for this loss in potency. Hatfield (1945) has stated that ultraviolet light causes some decomposition of pentachlorophenol and it is possible that other slow chemical changes may take place. Furthermore, it is impossible to prevent some mechanical loss of material from the surface of the blocks however carefully they are handled. Nevertheless, handling losses alone do not account for the large loss in potency which has occurred.

It is considered that the results show that pentachlorophenol has not the long term permanence which is necessary in a timber preservative when this material is used for pretreatment to prevent insect attack. On the other hand, as a residual contact insecticide pentachlorophenol

is the only material as yet tested which fulfills the requirements of efficient control of existing infestations of the common house borer, *Anobium punctatum.*

The dosages listed in this paper are not strictly comparable with the dosages as used in house treating. These are applied by flood spraying, while the dosages used in these experiments were applied by full impregnation under vacuum and pentachlorophenol may have concentrated at the surface as the solvent evaporated. However, it is considered that the experimental figures may be used as estimates of requirements in practice. Taking the figures in the tables above and calculating loss in potency, it would seem that efficient control demands the use of at least a 5 per cent. solution of pentachlorophenol. Given thorough application, a 5 per cent. solution could be relied on to give control of emerging *Anobium* for a period of from three to four years.

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AN INVESTIGATION INTO NUMBERS OF EGGS LAID BY FIELD COLLECTED *ANOBIUM PUNCTATUM* DE GEER

By D. SPILLER, Plant Diseases Division, Department of Scientific and Industrial Research

(*Received for publication, 14th May, 1948*)

Summary

Field collected *Anobium punctatum* females show great variation in numbers of eggs laid. As many lay none or very few eggs the frequency distribution of egg-laying is markedly skewed towards the lesser items. It was found that these skew distributions plot as straight lines when

frequencies of the cumulative distribution are converted to percentages and then to probits and these plotted against the square roots of numbers of eggs laid. Thus distributions are root-normal. With single females, curves are always truncated, while with groups of females the degree of truncation decreases as group size increases until, when sufficiently large groups of females are used distributions are truly root-normal. It is considered that skew distributions originate with methods of collecting and do not represent egg-laying in the field.

Females with extruded genitalia laid but few eggs. Size and activity were also correlated with number of eggs laid—small females and large active ones producing fewer eggs than large inactive females. Techniques for utilising females are discussed with reference to egg-laying distribution and it is considered that the present method of using from 15-25 females randomised as to both locality and date of collection is adequate. Two cages suited to *Anobium* work are described.

A DETAILED knowledge of the biology of the common house borer *Anobium punctatum* De Geer is necessary if adequate methods of control are to be evolved. Such knowledge is especially necessary for development of techniques for biological assay of timber preservatives.

The testing method that has proved suitable involves development of larvæ from the egg stage and does not start with partly grown larvæ. This has focussed attention upon the general biology of oviposition and especially upon the number of eggs laid by each female. The latter exhibits some unusual features and it is the purpose of this paper to present data available and to discuss origin and interpretation of these features.

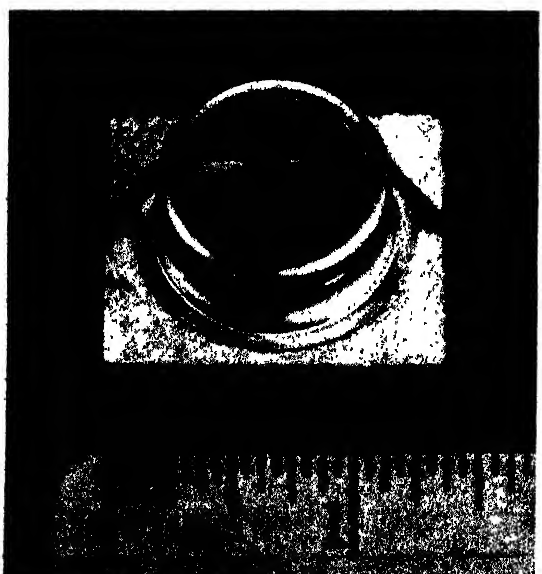

FIG. 1.—Type IV cage used with the single female technique.

The sexing method as described by Kelsey *et al.* (1945) has been used throughout this work. Beetles were collected from timber in the insectary and from infested buildings in and around Auckland city and then taken to the laboratory where each beetle was placed in a 5 x 1.5 cm. thin walled glass phial. The group from each collecting ground was sexed, counted, and recorded and then randomised with all other beetles

of the same sex that had been collected that day. Throughout subsequent handling, beetles were left in their tubes and removed only when it was necessary to form groups of known numbers of males, females, or both.

The cages used in obtaining egg-laying data were those described by Kelsey *et al.* (1945) and Types IV and V described below.

Type IV (Fig. 1). This cage was evolved for use with the single female technique (i.e. one female and one male to each test block) in which very large numbers of cages and blocks were handled. It has the advantage of confining egg-laying to one known surface of the block, thereby reducing labour of egg counting. With this cage, block size was 3.5 x 3.5 x 0.8 cm. with the 3.5 x 3.5 cm. face always the end grain of the wood, thus providing adequate egg-laying sites. The method of assembling cage and block is shown in Fig. 1.

These cages were produced in large numbers from tinned-plate using the dies normally employed to stamp blanks for inch screw-caps. The edge-turning, knurling and threading step was modified by eliminating these operations and substituting the depression of a single ring on the side of the cap one-quarter of an inch from the base flange. Cages were then fed through a press which punched a 7/10 in. hole in the top of each. The gauze circles were punched and snapped into position in one operation by feeding the cages through a wadding machine, but using brass gauze instead of waxed paper as the wadding strip. Cages of this type proved very satisfactory even on rough wood; the base flange prevented escape from under the cage and the gauze, although not soldered in position, fitted tightly.

FIG. 2.—Type V cage used with groups of females.

Type V (Fig. 2). Four ounce glass pomade pots with metal screw-on lids were used for this cage which is now being used for almost all our timber therapeutant testing. A $\frac{3}{4}$ in. hole is punched in the lid and brass gauze of suitable mesh soldered in position. Blocks are placed within the jar and beetles are introduced as required.

VARIATION IN EGG-LAYING

Kelsey *et al.* (1945) traced some of the excessive variation in number of eggs laid by *A. punctatum* to variations in sex ratio of randomly selected material. Introduction of sexing methods allowed the use of known numbers of females and eliminated this source of variation. Even so, variation was large and sufficient to mar some testing techniques evolved in this laboratory. In particular, assessment of results by statistical methods has been impossible, since frequency distributions of number of eggs laid are non-normal and approach the form known as extreme skew characterized by a preponderance of lesser items.

Three typical distributions are tabulated in Table I which also gives the average and maximum number of eggs laid.

TABLE I. FREQUENCY DISTRIBUTION OF THE NUMBERS OF EGGS LAID BY SINGLE FIELD COLLECTED ANOBIUM PUNCTATUM FEMALES

Number of eggs laid by each female.	Number of females laying this number of eggs.		
	Case A.	Case B.	Case C.
0	180	110	9
1	56	53	3
2	45	25	3
3	28	19	3
4	33	21	1
5	28	14	1
6	24	15	4
7	19	11	3
8	17	9	6
9	8	9	4
10	15	10	3
11	12	8	–
12	15	4	3
13	14	9	4
14	19	6	1
15	7	6	3
16	8	4	2
17	10	3	1
18	4	5	2
19	5	1	–
20	12	2	2
21–30	49	16	14
31–40	22	4	12
41–50	10	4	2
51–60	2	3	5
61–70	–	–	4
71–80	1	–	2
81–90	–	–	2
91–100	–	–	–
Total females	643	371	99
Season	1944–45	1945–46	1946–47
Dates Collected	25th Dec. -12th Jan.	8th Jan.	18th Dec.
Average eggs	8.3	6.2	22.0
Maximun eggs per female.	79	58	82

Single females have laid more than 50 eggs on many occasions and individual counts of 86 and 87 eggs have been recorded. From other evidence it appears that very rarely, if ever, does a female produce 100 eggs and that only about one in two thousand will produce more than 90 eggs, which for practical purposes may be regarded as the upper limit of the range.

In a previous paper (Kelsey *et al.* 1945) it was stated that the average number of eggs laid ranged from 15 to 44. Kelsey (1946a)

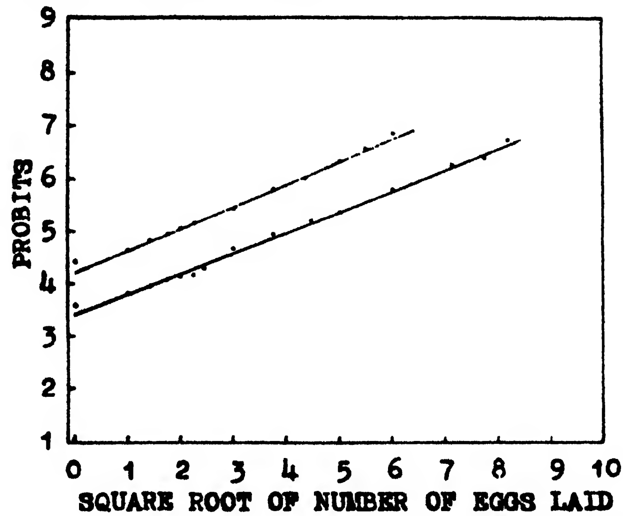

FIG. 3.—Probit-square root plot of number of eggs laid by *Anobium* females. *Upper line*: Cumulative plot of data of Case A, Table I. *Lower line*: Ditto Case C.

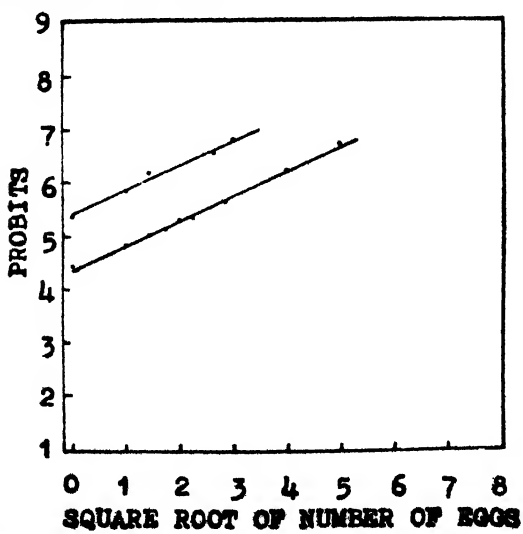

FIG. 4.—Probit-square root plot of number of eggs laid by *Anobium* females. *Upper line*: Cumulative plot of the 83 females with abnormal genitalia mentioned in text. *Lower line*: Ditto Case B, Table I.

recorded 42.7 on muslin and 34.9 on control blocks (1946b) while in this paper there are reported average values of 8.3, 6.2 and 22.0, for various years and times. This heterogeneity is explained by the fact that old females which have laid all or nearly all their eggs are collected in increasing numbers as the season progresses until almost all fall within this group. Thus at the beginning of the flight the average number of eggs produced is high and decreases rapidly until the end of the season. This is demonstrated by the figure 22.0 (18th December, 1946) and 6.2 (8th January, 1946) of Table I. Further figures on this point are not available but from experience it is known that females collected after the first week in January produce few eggs.

Skew distributions occur frequently in biology and while their treatment is of wide interest, the statistical aspects involved are not dealt with in this paper which is confined to identification of the distribution and a discussion of biological aspects.

Gaddum (1945) has pointed out that, when cumulative frequency totals are converted first to percentages and then to probits, and these are plotted against the measured variable, a straight line results when the distribution is normal. Likewise if the measurement variable is transformed to logarithms, a straight line results from log-normal distributions. Using these methods on the data in Table I a log-probit transformation gave marked curves. If, however, the square roots of the number of eggs laid are plotted against probits, straight lines result (Figs. 3 and 4). Gaddum (1945) also suggested a method of testing normality when the number of observations is limited, rendering it impossible to assess the frequency of the event. In this method the results are ranked and a parallel series of percentages [$(100(2r-1)/2n)$ where $n =$ number of observations and $r =$ rank] is formed, converted to probits and these values plotted against the transformation of the corresponding variable. Typical cases are shown in Figs. 5 and 6 where the square root of the number of eggs laid is plotted against the ranked probit. These eight cases show that while the frequency distribution is not normal, it can be normalised by transforming the number of eggs laid to their square root. It should be noted that with single females the frequency curve is truncated.

Egg-laying of groups of females duplicates that of single females and gives square-root normal distributions. As size of the group increases degree of truncation decreases (compare Fig. 5 left with Figs. 3 and 4) until truly root normal distributions are obtained (Fig. 5 right, Fig. 6). As is to be expected, the average number of eggs per female is similar and the range less per female.

While the large numbers of females which lay no eggs or very few eggs is characteristic of field collected *Anobium,* it is unlikely to represent egg-laying under natural conditions. Rather it would seem that this preponderance of lesser items originates with methods of collection and the known behaviour of beetles. Females spend considerable time in exit holes and here they lay many eggs. Daily collection of a small area occupies only a few minutes and the proportion of females collected to those present in the area is small. Some that are missed will be collected on the following and successive days. Beetles taken on the day of emergence may be regarded as virgin, but a day's collection comprises not only females emerged during the past twenty-four hours, but also some which have emerged on previous days and which have already laid a portion of their eggs. It is known that the last few eggs are laid over

a period of several days and that females live for some time after the last eggs are deposited. If it is assumed that females that have laid most of their eggs spend more time on the wood surface than those still actively laying, then the preponderance of lesser items in Table I is explained.

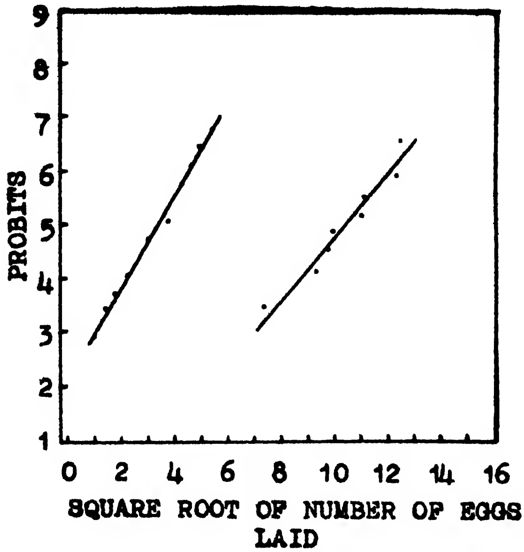

FIG. 5.—Probit-square root plot of number of eggs laid by *Anobium* females. *On left*: Cumulative plot on grouped data of 52 groups of seven matched pairs expressed as average eggs per female. *On right*: Ranked plot of total eggs on eight blocks each with seven matched pairs.

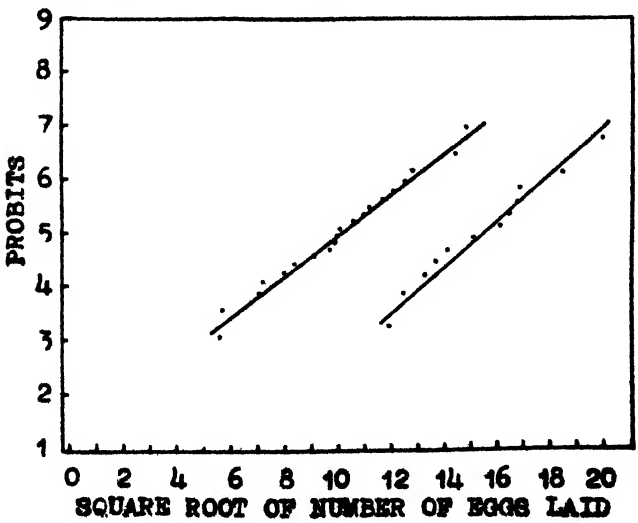

FIG. 6.—Probit-square root plot of number of eggs laid by *Anobium* females. *Upper line*: Ranked plot of 20 blocks each with four mated pairs. *Lower line*: Ditto twelve blocks each with 15 matched pairs.

At one time it was considered that the single female technique would be adopted as a standard testing method. A major difficulty was the large number of blocks on which few or no eggs were laid. Blocks with less than 10-15 eggs were unsuitable for testing purposes; about three-quarters of them fell in this category and these carried about 60 per cent. of the total eggs. This waste of eggs and the large amount of work involved in preparing and then discarding 75 per cent. of the blocks eventually necessitated abandonment of this technique, but before new methods were evolved, causes of this variation were investigated and an attempt made to select females for potential high egg-laying. The following criteria were used.

(a) *Abnormal genitalia*

In females the telson is normally mobile and retracted. Many females show deviations from this condition, especially a lack of mobility together with permanent extrusion of telson and surrounding tissue. Experience suggested that these abnormalities were associated with older females and that these laid few eggs. On 8th January, 1946, the day's collection of 457 females from nine collecting grounds was examined and 88 females were culled as showing typical extruded genitalia. Of these 83 were paired with healthy males and set up with one female per block. Number of eggs laid was 112, an average of 1.35 eggs per female; 53 females laid no eggs, 13 laid one egg, 7 laid two eggs and 3 laid four eggs each. The remaining seven females laid five, seven, eight, nine, ten, 12 and 22 eggs respectively. Seventy-five of the normal females treated in the same way laid 468 eggs, an average of 6.24 eggs per female, 15 averaging over ten eggs each. In a further test 50 females with extruded genitalia laid 126 eggs, an average of 2.52 per female, 19 laid no eggs and only three laid ten or more. This data shows that females with extruded genitalia produce few eggs and for testing purposes could be discarded.

(b) *Size and activity*

From the 369 normal females, which remained after culling those with extruded genitalia, 150 were taken at random for another experiment, while the remaining 219 were sorted into large and small females. These groups were kept separate during further sorting which was based on activity. Kelsey *et al.* (1945) mentioned that activity of males, measured by time taken to climb the sides of phials, gave an indication of physical well-being of the insects. Development of this method of assessing activity has been to tap the insects to the bottom of the tubes, stand these upright and after two minutes remove those in which beetles have crawled more than half way up the tube. Remaining tubes are swept into a box and after five minutes the process is repeated. These three classes are reported as firsts, seconds and residue. The numbers which fell in the various groups are shown in Table II.

TABLE II. CLASSIFICATION OF FEMALES ACCORDING TO THEIR ACTIVITY

	Firsts.	Seconds.	Residue.	Total.
Large females	61	28	37	126
Small females	52	16	25	93
Total	113	44	62	219

LAID BY FIELD COLLECTED *Anobium punctatum* DE GEER

Usually there is an excess of males at the beginning of the season, but by mid-flight numbers are about equal and excess females occur as the season draws to a close. Occasionally there are not enough males to allow all females to be paired and some have to be used without males. As there was insufficient knowledge of how absence of a male would affect egg-laying, groups with the highest activity were halved and used with and without males. The average number of eggs laid by each group is shown below (Table III).

TABLE III. AVERAGE NUMBER OF EGGS LAID BY FEMALES SORTED ACCORDING TO ACTIVITY

	Firsts.		Seconds	Residue.	Together.
	With males.	Without males.			
Large females	7.8	7.7	11.3	17.1	11.3
Small females	3.1	2.9	4.3	4.1	3.6
Together	5.7	5.4	8.8	11.9	8.0

It is clear that small females produced fewer eggs than did large females and that activity is not an adequate method of sorting small females for egg production. With large females the least active produced most eggs. Presence or absence of a male made no difference to egg production and it can be concluded that all females had been fertilized before collection. However, it is possible that earlier in the flight some females may be collected that have not been fertilized or perhaps more than one mating may be required to fertilize all eggs.

As details of egg-laying became known, methods of utilising females in cages were either modified or rejected. Of the four methods described by Kelsey *et al.* (1945) both the random (unsexed) and the method of mated pairs have been abandoned as unsuitable. The " female plus male " method is now standard and is subject only to variations in the number of females used in each cage. The single female technique was retained temporarily for assessment of the effects of contact insecticides (Spiller, 1948) but even this use has ceased now that the form of egg-laying distribution has been identified.

The present method is to use groups of from 15-25 females, randomised both as to locality and date of collection. The former is achieved by randomising all tubes of the same sex from all collecting grounds each day. As females are never held in tubes for more than one day the latter must be achieved by allocating beetles to each group at suitable time intervals throughout the season.

The fourth technique described by Kelsey *et al.* (1945) has not been further investigated as now no attempt is made to sort females or to discard those with abnormalities or injury.

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A NOTE ON THE SUSCEPTIBILITY OF HEAT TREATED WOOD TO ATTACK BY THE COMMON HOUSE BORER *ANOBIUM PUNCTATUM* DE GEER

By D. SPILLER, Plant Diseases Division, Department of Scientific and Industrial Research

(Received for publication, 12th September, 1947)

IT has already been shown that drastic heat treatments lower the equilibrium moisture content (E.M.C.) of kahikatea (*Podocarpus dacrydioides* A. Rich.), rimu (*Dacrydium cupressinum* Soland) and pine (*Pinus radiata* D. Don.) (Spiller, 1948a). As it was considered that such treatments might alter the liability of timber to attack by timber insects, investigations were carried out on the susceptibility of heated wood to the attack of the common house borer *Anobium punctatum* De Geer. Details of this investigation are given in the present paper.

The method of heat treatment was the same as that described in a previous paper (Spiller, 1948a), while the biological testing method was identical with that described by Spiller (1948b).

Design of the experiment was as follows:—Two random sap-wood boards of each of the two timbers, kahikatea and pine, were cut into blocks, approximately inch cubes. These blocks were formed into groups of 32, eight from each board, and each group was heated for 24 hours at one of the four temperatures, 105°c, 115°c, 130°c and 150°c. From every group two blocks of each board were tested for susceptibility to *Anobium*; two were retained for determination of E.M.C. The remaining four blocks were saturated with water and then allowed to dry. Two of the water treated blocks were tested for susceptibility to *Anobium* and two retained for E.M.C. determination. The water saturated series was included because it was considered that such treatments would alter the E.M.C. and thus give information on any possible effects of heat treatments not dependant upon changes in E.M.C. Such alteration did occur, the water saturated blocks averaging 0.7 per cent. higher in E.M.C. than the unsaturated blocks.

Results of susceptibility tests are shown in Table I.

TABLE I. EFFECT OF HEAT TREATMENT OF WOOD ON SUSCEPTIBILITY TO ATTACK BY *Anobium punctatum*

Timber Species.	Board.	Temperature of Treatment 24 Hours.							
		105°c		115°c.		130°c.		150°c.	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Kahikatea (*Podocarpus dacrydioides*)	A	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
,, ,,	D	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
Pine (*Pinus radiata*)	E	o +	+ +	+ +	+ +	+ +	+ +	o +	+ +
,, ,,	H	+ +	+ +	+ +	+ +	o +	+ +	+ +	+ +

o No live larvae present in block.
+ Live larvae present in block.

Results show that drastic heat treatment does not affect the liability of timber to attack by *Anobium.* Similarly, initial experiments demonstrated that kiln dried kahikatea (approximately 80°c.) was as liable to attack as air dried samples, which result is consistent with those given above.

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EFFECT OF HUMIDITY ON HATCHING OF EGGS OF THE COMMON HOUSE BORER *ANOBIUM PUNCTATUM* DE GEER

By D. SPILLER, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(*Received for publication, 27th November, 1947*)

Summary

Experiments on effects of controlled humidities (at 22.5°c.) on hatching of eggs of the common house borer *Anobium punctatum* De Geer showed that egg hatching is independent of humidity above 65 per cent. R.H., but is impaired between 50 per cent. R.H. and 60 per cent. R.H. No eggs hatched at 45 per cent. R.H. and below.

INTRODUCTION

INITIAL investigations on the use of the common house borer *Anobium punctatum* De Geer, for biological evaluation of timber therapeutants were retarded by an inadequate knowledge of the moisture requirements of this insect. In particular, the effect of different humidities on egg hatching was unknown. This problem was investigated during the 1942-43 flight periods. Some information has already been mentioned (Kelsey *et al.* 1945) and the remainder is presented in this paper.

METHODS

In this investigation the technique employed was to cage *Anobium* beetles with small blocks of wood at constant humidities. Under these conditions eggs were exposed to known humidity from the time of oviposition. Some months later the total number of eggs and percentage hatched was recorded.

Temperature and Humidity.

As the accuracy of control in humidity experiments is dependent upon constancy of temperature, all experiments were carried out in a temperature controlled room at 22.5°c. $\pm$ 0.5°c. Humidity control in the closed containers was secured by using potassium hydroxide solution, using the data of Buxton (1931) supplemented at higher humidities by data of Harned and Cook (1937).

Containers.

Type III cages as described by Kelsey *et al.* (1945) were used for all experiments. In the 1942-43 experiments large desiccators were used for humidity containers. In the following year independent humidity control of each replica was desired and suitable units were made from cut down vermouth bottles (Fig. 1). The potash solution was placed in the unit and the cage rested upon the raised pressure bottom of the bottle. Tops were closed by tightly fitting pressed tin lids sealed in position by water-proof sticking plaster. Daily ventilation was unnecessary because the potash absorbed the carbon dioxide produced by metabolism of the insects.

FIG. 1

Biological.

In the 1942-43 experiment 50 random beetles were used in each cage and in 1943-44 either three mated pairs or three matched pairs (male and female) per replica. The reasons for this change in technique together with the methods of collecting, handling and sexing of beetles, have been described by Kelsey *et al.* (1945).

Experimental.

In the 1942-43 experiment six replications were made at each humidity while in the 1943-44 experiment eight replications were used at each humidity with both mated and matched pairs.

RESULTS

In both years the total number of eggs at each humidity varied between 250 and 1,000 with average values of 300-350 per humidity in each experiment. The average hatching of eggs laid at each humidity is shown in Tables I and II below.

TABLE I. AVERAGE HATCHING OF EGGS OF *Anobium punctatum* AT VARIOUS HUMIDITIES (1942-43 EXPERIMENT)

Relative Humidity per cent.	15	27	40	50	60	70	80	90
Percentage of Eggs Hatched	0.0	0.0	0.0	69.7	75.1	92.8	93.4	87.2

TABLE II. AVERAGE HATCHING OF EGGS OF *Anobium punctatum* AT VARIOUS HUMIDITIES (1943-44 EXPERIMENT)

Relative Humidity per cent.	45	55	65	75	85	95
Percentage of Eggs Hatched (Mated Pairs)	0.0	73.1	90.8	88.3	85.0	89.2
,, ,, ,, (Matched Pairs)	0.0	53.9	82.9	93.0	87.2	81.0
,, ,, ,, (Weighted Mean)	0.0	65.2	89.0	90.0	85.8	87.1

Analysis of variance (after angular transformation of the data) indicates no significant differences in hatching between the humidities above and including 65 per cent. R.H. Humidities below and including 60 per cent. R.H. all show significantly lower hatching than the higher humidities. Although the embryo developed fully at humidities below 45 per cent. R.H., none of the eggs hatched, apparently because of an inability of the larvae to pierce the egg capsule.

In addition to the work reported here much data on egg hatching under both controlled and room conditions has accumulated and confirms the fact that egg hatching is little affected by normal variation in humidity. With large numbers of eggs the percentage hatching always falls between the limits 80-94 per cent. with average values around 89-91 per cent.

CONCLUSION

The effect of humidities of 65 per cent. and above on hatching of eggs of the common house borer *Anobium punctatum* is small and is unlikely to be a factor influencing incidence of infestation.

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LAPIEZ AND SOLUTION PITS IN BASALTS AT HOKIANGA, NEW ZEALAND

By J. A. BARTRUM and A. P. MASON, Auckland University College

(Received for publication, 28th May, 1948)

Summary

Description is given of lapiez-like fluting* or gashes and of solution pits which are wide, generally relatively short, vertical grooves with semi-circular cross-profile which end below in shallow basins. Both types of phenomena are unusual in that they occur in basalt and not in limestone, which is their usual host. The lapiez-like forms, which have developed on broad steep faces of blocks of rock, are ascribed to downflowing consequent streamlets fed by raindrip from overhanging forest trees; dissolved organic acids have caused solution of the basalt along the courses of these streamlets. The location of the miniature troughs so formed does not appear necessarily to be controlled by joints, but should these latter more or less coincide in direction with the general slope of a rock surface, troughs which otherwise would be shallow may be accentuated into deep gashes.

Solution pits have a comparable origin, but in this case the drip has been temporarily localized at isolated centres and has fallen upon subhorizontal rock faces.

* Some writers would use the term "lapiez" for this type of feature only when shown by limestones.

FIG. 1.—Lapiez in block of basalt near Horeke, Hokianga.
Photo: A. P. Mason

FIG 2.—Lapiez as in Fig. 1.
Photo: J. A. Bartrum

INTRODUCTION

As early as 1916 one of the present writers (J.A.B.) noted outstanding examples of fluting, comparable with that characteristic of many exposed faces of limestone, in basalts in the valley of a stream which enters Hokianga Harbour about half-a-mile west of Horeke Township and which is followed by the Horeke-Taheke Road. He did not realize until the appearance of a paper by Palmer (1927) describing similar forms from Hawaiian basalts that such occurrences apparently were somewhat rare and therefore did not record his observations. This is now being done because of a recent opportunity of obtaining photographs to illustrate the phenomenon.

LAPIEZ-LIKE FORMS

The fluting that is illustrated by Figs. 1 and 2 is shown only on the moderately steep sides of fairly isolated, large blocks of basalt fallen on to the lower slopes of the stream valley in question, or into its bed from a flow which has a maximum depth of not less than 60 ft., although its full thickness has not been determined. This flow overlies Upper Cretaceous sediments which in the vicinity of the main development of lapiez are likely to be soft shales, which are included amongst more resistant phases of the Upper Cretaceous sequence; actual outcrops, however, are absent from the particular locality. By stream and subaerial erosion the sheet of basalt has been undermined and has shed blocks of rock, some over 30 ft. in average dimension, which at times constitute a chaotic mass at the stream.

The fluting is developed generally on notably steep faces of relatively isolated blocks of rock which are seldom under 5 ft. in diameter and which typically have a sharp ridge-like crest. In some blocks, as is shown by Fig. 1, it appears that the fluting and more particularly deeper gashes are located along joints which have served to permit differential weathering along their traces, although they have not been sufficiently open to allow disruption of the blocks in which they occur. In other blocks, as can be seen from inspection of the photographs, the direction of fluting crosses joints obliquely and appears, therefore, to be independent of the latter. The troughs of the lapiez are generally spaced about 5 in. to 6 in. from axis to axis and are about 2 in. to 3 in. in average depth, unless excavated along joint fissures, when the depth may be much greater; between the troughs there are sharp-crested miniature divides.

SOLUTION PITS

Wentworth (1944) has recorded solution pits from Hawaii which, like those now described, typically are present on large, more or less isolated blocks of basalt or other igneous rock. The majority of the solution pits at Hokianga resemble roughly halves of wide tubes which have been divided longitudinally (Figs. 3 and 4). In many cases their bottoms are shallow basins, but in others, development of a lower pit in much the same vertical line as the upper has destroyed such basins. The width and depth of the "half tubes" usually do not exceed 1 ft., but occasionally the depth attains as much as 4 ft., though the width does not increase correspondingly. Possibly this extreme depth actually results from the union of members of a linked vertical series, for frequently these cavities occur one above another (Figs. 3 and 4) in a manner

FIG. 3.—Early Stages of solution pits in block of basalt near Horeke, Hokianga.

Photo: J. A. Bartrum

FIG. 4.—Solution pitting in block of basalt near Horeke, Hokianga.

Photo: J. A. Bartrum

suggesting that a lower member has been formed at times by overflow of water from the basin next above it.

In one abnormal example (Fig. 5) solution has led to a more or less disordered mass of hollows, some concave at the base but others irregular, separated one from another by irregular pillars or ridges with a height usually not much in excess of 1 ft., though some have much greater relief. In spite of the early impression of chaos in the pattern, there is a tendency to alignment of deeply etched hollows which are controlled in their location by joints which are evident in Fig. 5 to the left of and above the human figure.

ORIGIN OF LAPIEZ AND SOLUTION PITS

The conditions of occurrence make it impossible to ascribe the features described above to other than chemical weathering as the primary cause of their production. They are unrelated to irregularity either of surface or of constituent material, for the fairly fine-grained, generally ophitic and aphyric basalts in which they are developed are neither vesicular nor banded. Yet the process responsible for the etching of the grooves and gashes must have been controlled by special conditions, for the surface layers of the rocks concerned are fresh except where solution phenomena are lacking, when some slight degree of chemical weathering at times is detectable.

FIG. 5.—Solution hollows and intervening eminences in block of basalt near Horeke, Hokianga.

Photo: J. A. Bartrum

Bell and Fraser (1912, p. 47) state that in rhyolitic fragmental rocks of the Waihi-Tairua region of Auckland Province "white walls of rock, frequently scored with vertical flutings or corrugations, recall familiar topography in limestone country." This brief statement suggests that this corrugation does not occur on fallen blocks; in contrast, so far as

the present writers have yet seen, in basalts it is limited to such blocks. Besides the examples selected for description in this paper, fluted basalts occur fairly freely in valleys closely adjacent to these latter and have been reported* from other North Auckland localities and from the east end of Waiheke Island, Hauraki Gulf (E. J. Searle). The fluted blocks invariably are large and have been shed by thick flows with major joints very widely spaced. The size of such blocks would appear to be a pertinent factor in the development of solution phenomena, for, under the hypothesis of origin that is advanced, it would be necessary for the blocks to maintain a stable attitude for an unknown but certainly lengthy period which may well have exceeded a thousand years. It is probable that only blocks of unusually large size would normally attain stable positions after gravitating from higher to lower levels; in addition it is believed that as a rule a certain minimum and not inconsiderable area of rock surface is demanded before the genetic process can come into operation.

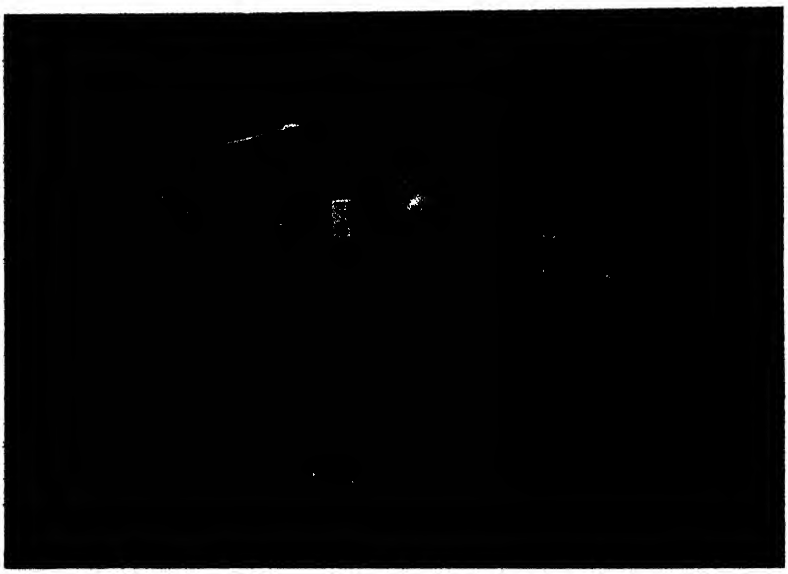

FIG. 6.—Exaggerated solution "pits" in block of basalt near Horeke, Hokianga. The elongated furrow to the right of the hammer appears to consist of two conjoined "pits".

Photo: A. P. Mason

Wentworth (1944) has suggested that drip of rain from trees has largely been responsible for the lapiez and other solution forms that he describes from basalts and other igneous rocks at Hawaii. Such drip appears to be the explanation also of the comparable features of the Hokianga rocks, for these latter invariably occur in areas where prior to deforestation there was a forest cover. Drip from many New Zealand forest trees during heavy rain tends to be concentrated at some points rather than others, falling with particular emphasis from such places as junctions of major branches and the undersides of large sub-horizontal limbs. No rainfall figures are available for the Horeke district itself, but rainfall maps (Kidson, 1937) show that on ranges close at hand, which

* Oral communications.

attain a maximum elevation of over 2,500 ft., the mean annual precipitation may exceed 200 in., although elsewhere in the Hokianga region it may fall as low as 60 in. In North Auckland much of the rain comes during periods of heavy downpour which are separated by spells of a week or two during which the rainfall is slight.

During bursts of heavy rain the drip from trees can be particularly intense and will wash organic acids from the decaying bases of mosses, species of *Astelia* and other epiphytes which abound in the local forests. It is believed that these organic acids have a highly important rôle in decomposing the minerals of the basalts; both olivine and the lime-rich feldspar that is one of the main constituents of these rocks are likely to be decomposed readily by such acids.

Where the surface of a block of rock has been more or less horizontal, drip concentrated into a somewhat cylindrical mass can be expected to dissolve initially a shallow cup-shaped hollow such as is shown in Fig. 6 on the right hand half of the block figured. The hollow to the left in which the match box appears, is typical of the usual solution pit; its base is slightly concave so that it holds, during and following rain, a small, shallow sheet of water from which, in the present instance, overflow occurs at two points on the outer margin, the courses of the resulting streamlets being defined by dark linear patches in the photograph. The writers suggest that the reason why a cylindrical hollow comparable in form with a stream pothole has not resulted, is that overflow from the lowest part of the rim of a growing cup-like hollow has continuously dissolved this part of the rim as deepening proceeded. Such overflow may be responsible for the production of series of such forms in which one is perched above another, but, as will be suggested later, another cause may operate.

In connection with typical lapiez shown by the basalts, it is true that in some instances weathering along joints almost certainly has early given rise to slight troughs which have then initiated small streamlets; these have passed down the rock faces and deepened such initial hollows largely by the chemical action of dissolved organic acids. Inspection of Fig. 2 will show, however, that the direction of fluting may be independent of joints which ostensibly should have exercised directional control. It is probable in this latter case that, on suitable steeply inclined surfaces, rain drip has given rise to minute consequent streams which have recurred in the same embryo channels at successive bursts of rainfall and thereby have continuously deepened them into typical lapiez. Hitchcock (1947) ascribes coarse fluting in granite in the Orinoco-Ventuari region of Venezuela to minute invisible joints, for in a few cases the fluting is parallel to joints along which the blocks have split apart. Such joints as there are in the Hokianga rocks, however, are far from regular in their trend and do not appear to play an essential rôle.

The reason for the lack of appreciable weathering in the rock closely associated with the solution features described is apparently that materials disintegrated by the chemical activity of organic acids in waters passing over the rock surfaces are immediately carried off by the swiftly moving, drip-fed streamlets which occupy the troughs and other hollows.

It has been suggested above that considerable time may be involved in the production of lapiez and solution pits. It does not appear, however, to be essential that the drip from trees fall from identical spots during the whole of the process. The individual trees of the forest must change

and be replaced by others as time goes on. Yet, once the formation of troughs or pits was well in hand, should change of location of major rain drip be altered by change in forest conditions, much of the water would still find its way into the prepared depressions and extend them by solution. Under suitable conditions, however, it seems likely that fresh solution pits could be developed on a flattish rock surface and it is highly probable that this is the explanation of some of the members of the vertical series of linked solution hollows that have been described.

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REVIEW

AN INTRODUCTION TO THE THEORY OF SEISMOLOGY

By K. E. Bullen. Pp. xii + 276. (Cambridge University Press, 1947.)

Professor Bullen's previous association with New Zealand seismology lends an extra interest to this book for New Zealand readers. The earlier chapters, on elasticity theory, vibrations, and waves, are based on lectures given to students of applied mathematics in Auckland and elsewhere. Use is made of Cartesian tensors, in the interests of terseness, but a previous knowledge of tensor theory is not demanded. Later chapters are concerned with seismograph theory, the construction of travel-time tables, observatory organization and methods, the earth's upper layers, the deep interior and central core, general features of earthquake occurrence and distribution, and a brief treatment of earthquake effects, sea disturbances, and microseisms. Much of the latter part of the book can be read without much mathematical attainment.

A feature of this book is that it brings together in compact form so many of the important contributions to seismological theory made by Jeffreys, and by Bullen himself, who has been a pupil and collaborator of Jeffreys. The range of this work has been wide - - - elastic wave-theory, deductions of internal structure from (T, Δ) relations, statistical treatment of observatory data and the construction of the J-B travel-time tables, corrections for ellipticity, density-variations and gravity-values inside the earth, the elastic parameters of solids and liquids, and so on.

The scope for seismological research in New Zealand is very large, and there is hope that with recent additions to Observatory establishments, the prospect of sufficient instruments in the local seismograph network to enable satisfactory statistical studies, and the inclusion of seismology in the University Applied Mathematics curriculum, progress in this science, important as it is to many aspects of New Zealand economy, may be more rapid than has been possible hitherto. Professor Bullen is unfortunately no longer with us to inspire a school of seismology, but his book, especially on account of its clarity of style, will be a valuable introduction to the subject for the academic or professional student, while the general reader who is prepared to take the mathematical results for granted can get much information on modern developments in seismology from the latter part of the book.

W. M. J.

A RECENT FAULT SCARPLET AT THE OUTLET OF LAKE HAUROKO, SOUTHLAND

By B. L. WOOD, New Zealand Geological Survey, Department of Scientific and Industrial Research

(*Received for publication, 30th May, 1947*)

Summary

An account is given of a small recent fault and the local geology near the outlet of Lake Hauroko, Western Southland. It is accompanied by a geologic map and an air photograph of the area.

INTRODUCTION

WHILE studying aerial photographs of the region around Lake Hauroko, a prominent straight line was noticed in the forest shading on each side of the Wairaurahiri River, intersecting the course of the river almost at right angles, and approximately 16 chains downstream from the lake outlet. This feature was paid special attention while on a geological reconnaissance of the country during January 1948, and proved on examination to be a fault scarplet produced by recent movement.

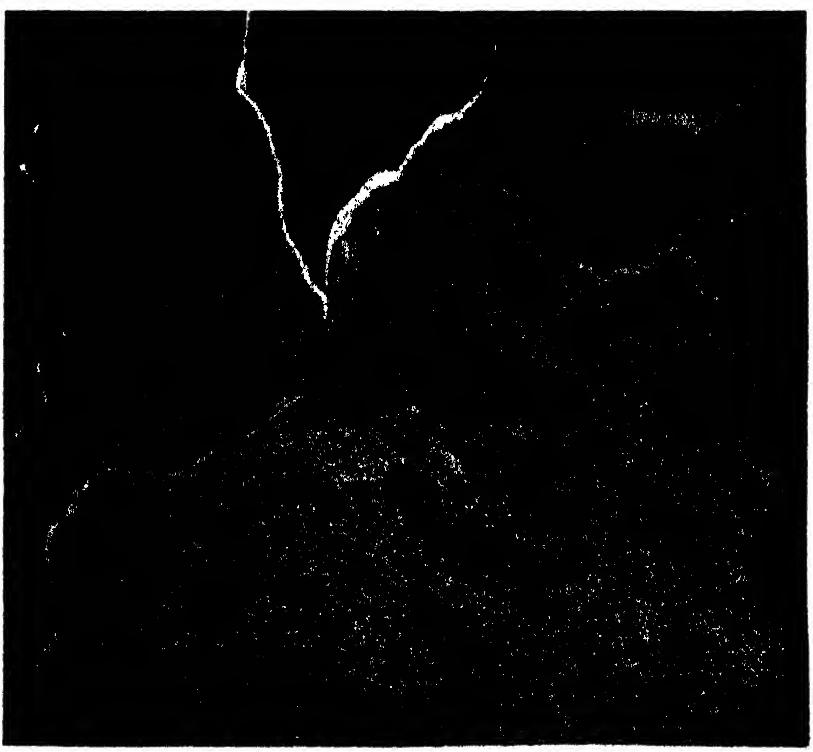


FIG. 1.—Air photograph of the area.

LOCAL GEOLOGY

The course of the Wairaurahiri from the lake outlet to the fault is antecedent and lies in a small gorge cut through moderately hard, fine-grained, Tertiary sandstone, slightly calcareous and blue-grey on fresh exposures. This rock weathers to a soft, yellow or brown, lightly jointed sandstone, for a depth of 2-3 ft. It crops out along the western shore of Lake Hauroko for as far as 70 chains from the outlet, the whole being overlain by fluvioglacial and deltaic deposits of rounded gravels and sands. The sandstone occurs for a short distance along the eastern shore, but is largely obscured by talus from the adjacent Hump Ridge. High bluffs, 20 chains back from the eastern shore, mark the boundary of the coarse sandstone and conglomerate making up Hump Ridge. These are strongly jointed rocks of variable grade, but of uniformly great hardness, grey or greenish, and weathering brown. Their attitude is variable owing to small local movements, but the structure is essentially an anticline with its axis trending north-north-east.

On the downstream side of the fault the river is considerably wider and flows between low banks of river and terrace gravels. These extend for some distance on each side, almost totally obscuring the underlying Tertiary sandstone which is similar to that occurring upstream from the fault. The attitudes of rocks to the south-west suggests that the fine-grained sandstone adjacent to the lake outlet is overthrust from the north-west by the hard and resistant gneissic rocks of the Fiordland metamorphic complex and is pinched out against the only slightly resistant rocks of the Hump Ridge.

SURFACE EXPRESSION OF FAULTING

Extending on each side of the Wairaurahiri River from the upstream side of the large pool shown on the map is a low step in the land surface 2 ft. 6 in. to 3 ft. high.

To the west, this feature may be traced on the air photographs on both land surface and tree-top level to a short distance beyond the Rata Burn, in the course of which stream a small amount of widening is noticeable at the point where the fault crosses it.

To the east, the same low bank extends up to a small stream, the upper part of which is oriented along the fault zone approximately 30 chains from the river. For a distance of about 10 chains further up this stream, slumping has occurred between two very straight, low, heaped ridges about 3 ft. high and 30 ft. apart.

The rock within this zone has yielded readily and is deeply weathered to a soft, blue-grey, puggy clay which forms a very mobile lubricant for both slumping and faulting movements.

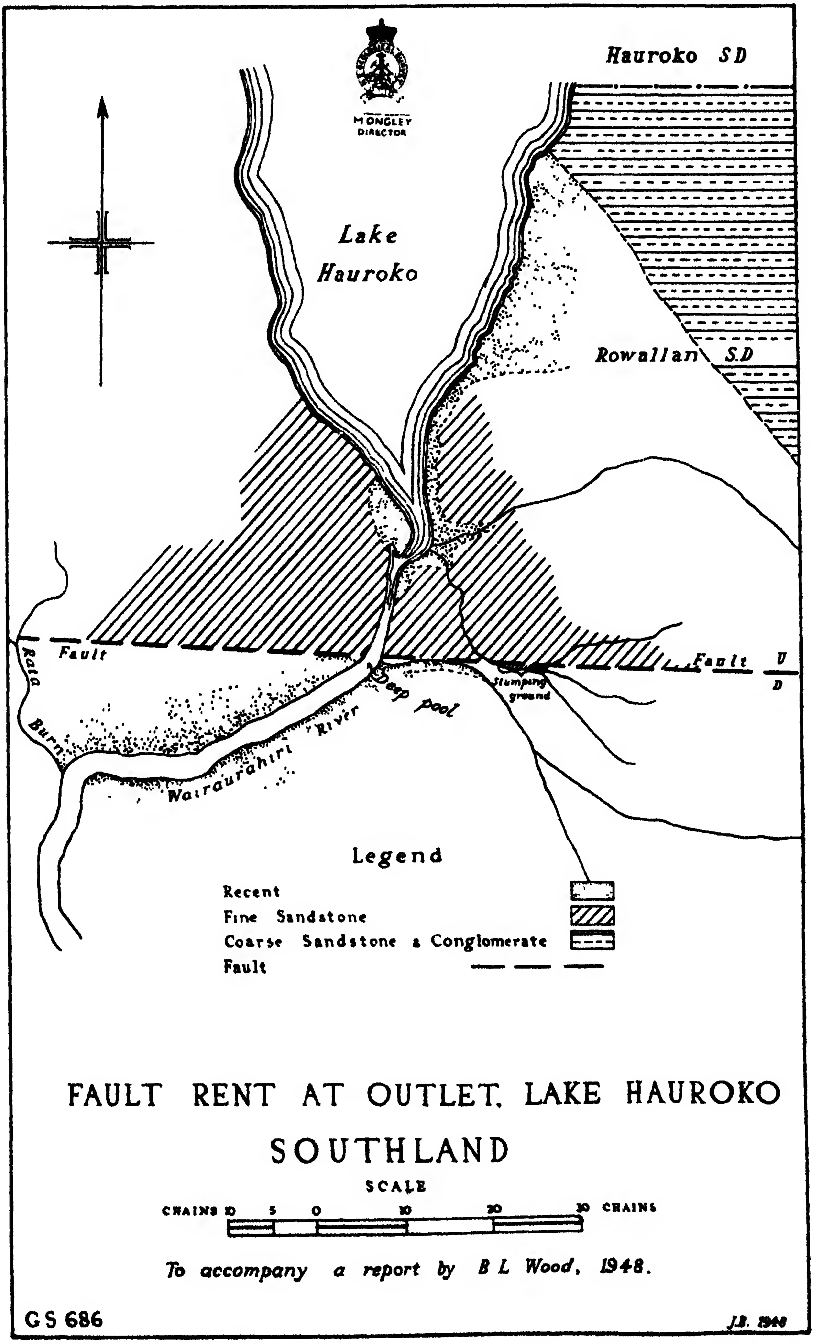
Beyond the slumped area, the fault trace is discernible, as a step of decreasing height, almost to the top of the main ridge of the Hump where it is lost among numerous, steep gullies.

MOVEMENTS

The primary movement resulted in a vertical throw of 2½ to 3 ft.; this is shown by a step in the land surface. The formation of two small sandstone ridges along the line of the fault, to the east of the Wairaurahiri River is probably due to the presence of a second, smaller fault, parallel to, and south of, the larger. It is unlikely that the area between the ridges is a pug zone because a small movement of so recent occur-

rence could hardly have formed such a wide zone. This fault is also at right angles to the main local geological trends, so that it is unlikely that it is the rejuvenation of an older, larger fault.

FIG. 2



On examination of the growth rings, the age of saplings growing on the small ridges proved to be forty-five to fifty years. Allowing a maximum of ten years for germination of the seeds, this places the age of the fault at sixty years and the first occurrence at about 1888.

At one or two places in the slumped area a second trace is observable, as a small ridge 2½-3 in. in height low down along the side of the larger ridge. The growth of mosses and small plants along it indicates that a small movement of a few inches has occurred within the last 4-5 years.

Since the upthrow side of the fault as a whole is toward the main mass of the Fiordland complex to the north, and the strike is perpendicular to the main geological trends and structure, a suggestion is advanced that the movement represents the slow rise of the Fiordland massif as an isostatic adjustment, following the disappearance of the Pleistocene ice sheets and glaciers.

SUBJECT: ESTIMATIONS OF HOURLY VALUES OF SOLAR ULTRA-VIOLET RADIATION IN NEW ZEALAND

By E. R. COOPER, Dominion Physical Laboratory, Lower Hutt

(*Received for publication, May, 1948*)

Summary

Calculations of hourly values of ultra-violet (wavelengths less than 3200 Å) radiation intensity for the twenty-first day of each month have been made.

INTRODUCTION

OBSERVATIONS of the intensity of solar ultra-violet radiation of wavelengths shorter than 3200Å have been reported by Coblenz and Stair (1) for the period 193€-1942 inclusive. The measurements which refer to the clearest days only, were made with a photo-electric cell directed towards the sun and having a 22° aperture with the sun as centre. The intensities in microwatts per square centimetre are plotted versus air mass for each year. Air mass is a relative measure of the thickness of the earth's atmosphere traversed by the sun's rays and is expressed by the secant of the sun's angular distance from the zenith of the sky.

The ultra-violet intensity for a given air mass is greatly influenced by the clarity of the atmosphere and by its ozone content so that the large number of observations for any year, when plotted, do not by any means lie on a smooth curve. A mean curve however can be drawn as in Fig. 1 which fits roughly the mean of the plots for each of the six years' observations given by Coblenz and Stair.

The latitude of Washington where these data were obtained is 38.9°N. and it can be expected that the data will be equally applicable to a similar latitude south of the equator. The data will therefore be of interest to workers in New Zealand and the object of this brief paper is to present a rough estimate of the comparative total daily amounts of ultra-violet radiation of wavelengths less than 3200Å which may be anticipated on the average on clear sunny days in this country.

(a) as between summer and winter for a given locality ;

(b) as between one locality and another in New Zealand for a particular season.

The localities which have been chosen are Lincoln (latitude 43.6°s.), Wallaceville (41.1°s.) and Ruakura (37.8°s.).

TABLE 1

t hours before or after noon	E = 23.5° June 21		E = 20° 12′ July 21 May 21		E = 11° 30′ Aug 21 April 21		E = 0 Sept. 21 March 21		E = −11° 30′ Oct 21 Feb. 21		E = −20° 12′ Nov. 21 Jan. 21		E = −23.5° Dec. 21	
	Air Mass	U.V. $\mu W/cm^2$	Air Mass	U.V. $\mu W/cm^2$	Air Mass	U.V. $\mu W/cm^2$	Air Mass	U.V. $\mu W/cm^2$	Air Mass	U.V. $\mu W/cm^2$	Air Mass	U.V. $\mu W/cm^2$	Air Mass	U.V. $\mu W/cm^2$
LINCOLN COLLEGE LATITUDE = 43.64° SOUTH														
0	2.57	15	2.27	22	1.75	50	1.38	82	1.18	106	1.09	121	1.06	126
1	2.73	12	2.39	19	1.82	46	1.43	76	1.21	102	1.12	116	1.09	120
2	3.33	6	2.86	9	2.10	29	1.59	62	1.33	88	1.21	102	1.18	106
3	5.14	0	4.13	0.5	2.75	11	1.95	37	1.56	64	1.39	80	1.34	86
4					4.60	0	2.76	11	2.03	32	1.73	52	1.65	58
5							5.33	0	3.11	7	2.41	18	2.24	23
6											4.20	0	3.64	4
Total Daily U.V. G. cal./sq. cm.		.042		.070		.191		.390		.596		.740		.791
WALLACEVILLE LATITUDE = 41.12° SOUTH														
0	2.33	21	2.08	30	1.65	57	1.33	87	1.15	110	1.07	124	1.05	131
1	2.47	17	2.19	25	1.72	52	1.37	83	1.18	106	1.10	118	1.08	122
2	2.97	8	2.59	14	1.97	36	1.53	67	1.30	90	1.19	104	1.16	108
3	4.42	0	3.66	4	2.56	15	1.88	41	1.53	66	1.38	82	1.33	87
4				0	4.20	0	2.65	13	2.00	34	1.72	52	1.64	58
5							5.13	0	3.10	8	2.44	17	2.27	23
6											4.4	0	3.81	3
Total Daily U.V. G. cal./sq. cm.		.061		.098		.227		.426		.616		.755		.811
RUAKURA LATITUDE = 37.77° SOUTH														
0	2.08	30	1.88	41	1.53	66	1.26	95	1.11	117	1.05	131	1.03	135
1	2.19	25	1.98	35	1.59	62	1.31	90	1.15	109	1.08	122	1.06	127
2	2.60	14	2.32	21	1.82	56	1.46	73	1.26	94	1.17	107	1.14	112
3	3.72	4	3.19	7	2.34	20	1.78	49	1.49	70	1.36	84	1.32	88
4					3.76	4	2.52	16	1.96	36	1.71	53	1.64	58
5							4.88	0	3.09	8	2.47	17	2.31	21
6											4.72	0	4.09	1
Total Daily U.V. G. cal./sq. cm.		.100		.143		.283		.476		.641		.770		.823

OUTLINE OF CALCULATIONS

The total daily ultra-violet radiation can be obtained from Fig. 1 by first calculating the air mass versus time of day for a given month and latitude, and then deducing the ultra-violet intensities for various times of the day from Fig. 1. The resulting curve in which ultra-violet intensity is plotted against time of day is then integrated to give the total daily amount of radiation.

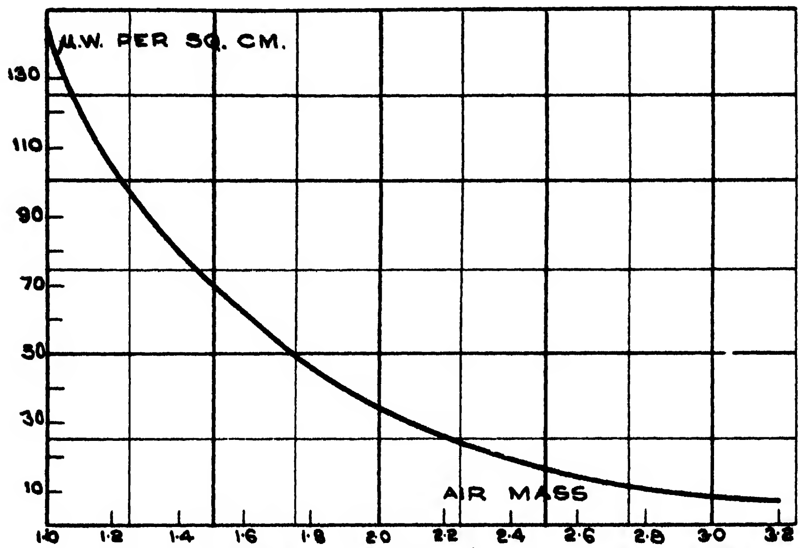


FIG. 1. U.V. SOLAR RADIATION (λ < 3200 Å) VERSUS AIR MASS

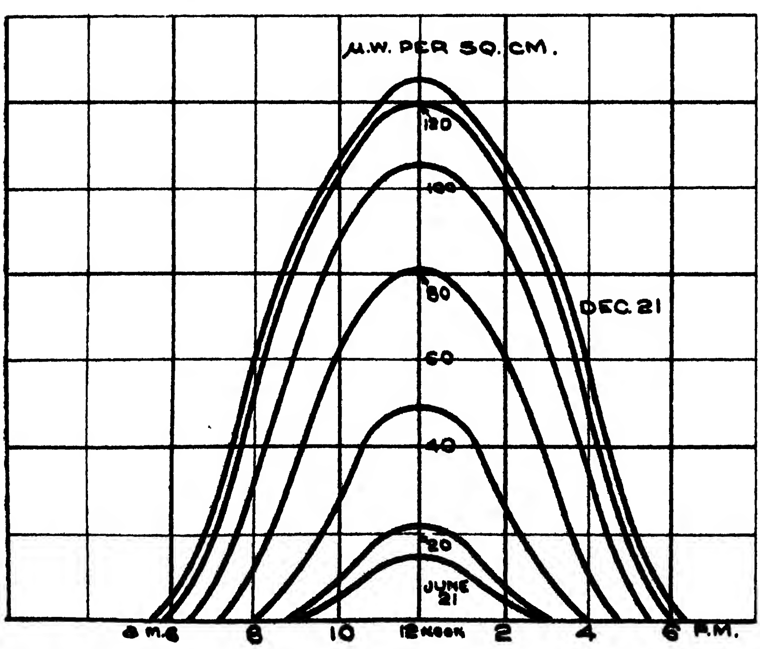


FIG. 2. U.V. RADIATION AT LINCOLN JUNE 21 – DEC 21

The air mass is derived from the solar altitude. The angle θ between the sun's rays and the zenith at a latitude λ is given for any time t of the day by the formula (see appendix).

$$\cos\theta = \cos 15t^\circ \cos\lambda \cos E - = \sin\lambda \sin E$$

where t = time in hours before or after midday

E = angle between the sun's rays at midday and the zenith at the equator. E is reckoned positive when the sun lies north of the equator and is taken to vary from $23\frac{1}{2}^\circ$ (21st June) to $23\frac{1}{2}^\circ$ (21st December).

The air mass, as previously mentioned, is measured by secant θ.

RESULTS OF CALCULATIONS

Table I gives the values of sec. θ = air mass and of the ultra-violet intensity in microwatts per sq. cm., at hourly intervals for the twenty first day of each month. Fig. 2 gives as an example the daily curves for the ultra-violet radiation at Lincoln The total daily ultra-violet radiation in gram calories per sq. cm. is obtained by integration, by means of a planimeter, of the daily curves, and these totals are also given in Table I.

The results are extremely illuminating. Of major interest are the facts :-

(1) that at the higher latitude (Lincoln) the difference in ultra-violet radiation between summer and winter is more marked than at the lower latitudes; at Lincoln the ratio is of the order of 20 and at Ruakura only 8 :

(2) that the ratio of the ultra-violet radiations for stations of high and low latitudes reveals a larger proportionate difference in winter than in summer; for example the ratio of the ultra-violet radiation received on 21st June at Wallaceville to that received at Lincoln is 1.5 whereas on 21st December this ratio is 1.02 approx. Moreover since the data are derived only for a 22° portion of sky including the sun it is likely that this difference would be still greater for sun plus total sky radiation.

It must be re-emphasized that the above data apply only to clear days. Meteorological factors such as cloud amount, ozone content and atmospheric polution due to smoke and dust will influence the transmission of ultra-violet on any particular day. From the scattering of the values of ultra-violet radiation intensity observed by Coblenz and Stair, the actual intensity on any clear day particularly for low values of air mass (i.e. mid-summer) may differ by as much as $\pm$ 30 per cent. from the average values given in Fig. 1. This variation is largely due to ozone and it shows clearly that ultra-violet radiation like any other meteorological factor must be recorded in order to know what has transpired on any particular day or during any season.

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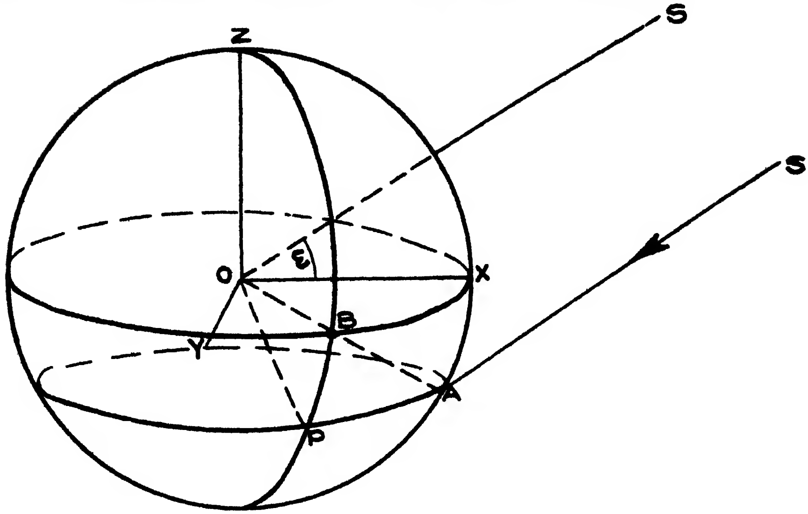


FIG. 3 (APPENDIX)

APPENDIX

In Fig. 3 let O be the centre of the earth and let the sun's rays be parallel to the coordinate plane ZOX, so that the sun is at its greatest altitude with respect to localities lying on the longitude formed by the intersections of ZOX with the earth's surface. Let A be one of these localities for the particular latitude that we are interested in. Then OA is the zenith line for this locality at mid-day, let OP be the zenith line of the same locality at t hours measured plus or minus from mid-day.

If l, m, n are the direction cosines of the zenith OP for the locality at P then

$$l = \cos POX \qquad m = \cos POY \qquad n = \cos POZ$$

The spherical P X B has a right angle at B hence

$$\cos PX = \cos BX \cos PB$$
$$= \cos \frac{\pi}{12} t \cos \lambda$$

Similarly the spherical triangle PBY has a right angle at B hence

$$\cos PY = \cos BY \cos BP$$
$$= \sin \frac{\pi}{12} t \cos \lambda$$

Therefore $l = \cos \frac{\pi}{12} t \cos \lambda$, $m = \sin \frac{\pi}{12} t \cos \lambda$, $n = -\sin \lambda$

If l^1 m^1 n^1 are the direction cosines of the sun's rays SA then

$l = \cos E$ where E = angle between the sun's rays and the zenith OX at the equator at mid-day. E is reckoned positive when the sun lies north of the equator

$m = o$

$n = \sin E.$

The angle between the sun's rays and the zenith OP is given by

$$\cos \theta = ll^1 + mm^1 + nn^1$$
$$= \cos \frac{\pi}{12} t \cos \lambda \cos E - \sin \lambda \sin E$$
$$= \cos 15t^\circ \cos \lambda \cos E - \sin \lambda \sin E$$

The angle E between the sun's rays and the equatorial plane is easily shown to be given by

$\sin E = \sin 23\tfrac{1}{2}^\circ \cos 30T$ where T is the time in months measured from 21st June.

THE MEASUREMENT OF SOLAR PLUS SKY ULTRA-VIOLET RADIATION

By E. R. COOPER, Dominion Physical Laboratory, Lower Hutt

(*Received for publication, May. 1948*)

Summary

A brief resume is given of the stage reached at the Dominion Physical Laboratory on the problem of making a continuous daily measurement of the ultra-violet radiation received at the earth's surface from the sun and sky.

THE object of this paper is to give a resume of the problem of measuring the total energy of radiation of wavelengths shorter than 3200 Angstroms received at a fixed point on the earth's surface from the sun and sky. This problem which has again occupied our attention at the Dominion Physical Laboratory since the termination of the war, is of interest in New Zealand because it has a bearing on certain biological experiments being carried out. The wavelength 3200Å has been arrived at (1) as the long wavelength limit of the biologically effective radiation.

Although the radiation incident on a flat horizontal surface may not be identical with that incident on an animal or plant, yet it will yield a means of comparing the amounts of radiation received at various times of the day or days of the year and is therefore chosen as the only practicable basis of measurement.

The problem of measuring the ultra-violet radiation of the sun and sky first arose in connection with the investigation of physical factors (2) that might be associated with the occurrence of outbreaks of facial eczema in sheep and cattle in New Zealand in 1934/35 and 1937/38. W. W. Coblenz and R. Stair of the National Bureau of Standards were at that time making measurements of the direct rays of the sun and their technique was adopted as being the most practical available means of making the required measurement. Their method consisted briefly of using a photo-electric cell, sensitive only to wavelengths less than 3120Å, together with a D.C. amplifier. The use of filter radiometry had been adandoned by the U.S. Bureau in favour of the photo-electric cell.

As a result of the U.S. Bureau work, there have been published (3) a series of tables giving the spectral energy distribution of the sun's ultra-violet radiation for various air masses.* These tables which were the subject of correction by later work (4) are essential for the continuous daily measurement of sun plus sky ultra-violet radiation, for the Bureau's work indicates (5) that the spectral energy distribution can be related to the air mass for a given elevation above sea level and that it is practically independent of the amount of cloud in the sky. This latter fact offers a considerable simplification in that photo-electric cell readings can be corrected for time of day according to the spectral energy distribution pertaining to the air mass at that time without need for recording the distribution. No doubt this is approximate

* Air mass is a relative measure of the thickness of the atmosphere traversed by the sun's ray and is expressed by the secant of the sun's angular distance from the zenith.

only but it is an approximation to be grasped at if continuous daily records are to be proceeded with. If greater precision is required, we are faced with a rather impracticable alternative which demands the recording of the spectral energy distribution and a consequent complex reduction of a mass of recorded values obtained from each daily record.

Pollution of the atmosphere by smoke and dust does affect the spectral energy distribution and will therefore affect the accuracy of the information obtained by the above method. However the influence of fog and cloud on the distribution is slight at the ultra-violet end of the spectrum and hence it does seem possible, using photo-electric cells, to obtain for most New Zealand localities, an approximate measure of the total ultra-voliet radiation from the sun and sky without the employment of any device for continuously or repeatedly measuring the energy distribution.

OUTLINE OF BASIS OF MEASUREMENT

If absolute determinations of radiant energy are required it is necessary to know (a) the spectral response curve of the photo-cell to be employed and (b) the output of the cell for an incident radiation of known energy and wavelength. At present it is not possible to perform these calibrations at the Dominion Physical Laboratory in the absence of an ultra-violet spectrometer and radiometer.

Fig. 1 depicts the three curves with which we are concerned. When the photo-electric cell is exposed to a source of known spectral energy

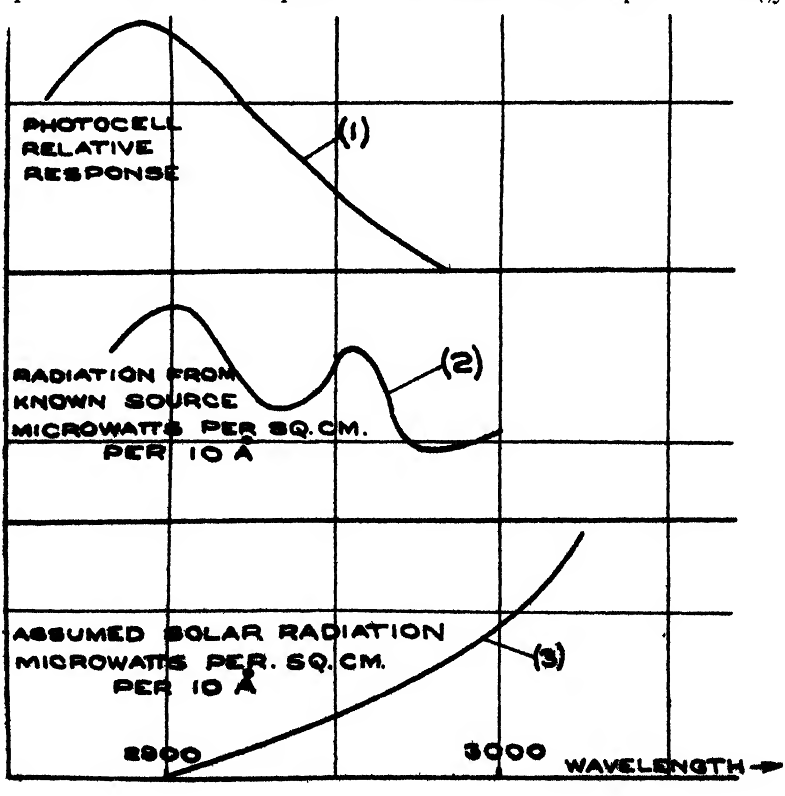


FIG. 1

distribution (curve 2) the reading of the meter which it operates will be a measure of the integral of a curve formed by the product of the ordinates of curves 1 and 2. We can, for brevity, term this integral the "effective radiation." The photo-cell meter measures then the effective radiation ; in fact we can write :—

effective radiation = constant × photo-cell meter reading.

The constant is determined by this exposure of the cell to a known spectral energy source.

Suppose now the photo-cell is exposed at a given air mass to the radiation of the sun and sky. The relative spectral energy distribution for the sun and sky is known from references (3) and (4) for the particular air mass.* We assume a curve 3 for the sun and sky radiation which must agree with the known distribution. The integral of a curve formed by the product of the ordinates of curves 1 and 3 will yield a value of effective radiation which may or may not agree with the meter reading ; if it does not so agree then the ordinates of curve 3 will require to be either all increased or all decreased by a fixed ratio for all wavelengths until agreement is reached.

Coblenz, Gracely and Stair have given a method whereby it is possible to calibrate a second photo-cell by reference to a standard photo-cell which has been subjected to the above procedure. The two cells (operating their associated meters) are simultaneously exposed to the sun and sky and the ratio of their meter readings is plotted against air mass. Smooth single-valued curves are obtained as depicted by A in Fig. 2.

The radiation at any air mass is deduced from the reading of the second photo-cell's meter by the relation :—

$$\text{radiation} = \text{photo-cell meter reading} \times \frac{B}{A}$$

That such a calibration is possible is completely dependent upon the fact that, for a given air mass, the relative spectral energy distribution of the ultra-violet radiation from the sun and sky is fixed.

For our purposes this type of calibration could be done at Washington and would need to be extended over all air masses that would be encountered at the particular station in New Zealand at which we require to make measurements. It does not matter that the cathode of the photo-cell chosen may not be sensitive to wavelengths as long as 3200Å, for the calibration curve B in Fig. 2 can be presented in such a way that the energy comprised by wavelengths 3200Å and shorter in the solar spectrum is the quantity concerned. This type of calibration would not enable the cell to be used for measuring the ultra-violet from any other source than the sun and sky at sea level* in mid-latitudes.

CONSTRUCTION OF EQUIPMENT

The next problem is the construction of the photo-electric cell so that it will measure the whole radiation of the sun and sky incident on a small horizontal surface. The only photo-cells we have been able to

* Air mass is related to the time t of the day and to the day of the year by the formula :—

$$\text{air mass} = \sec\theta \quad \frac{1}{\cos 15t \cos\lambda \cos E - \sin\lambda \sin E}$$

where λ = latitude south
t = time in hours before or after midday
E = ecliptic angle corresponding to the day of the year and varies from $+23\frac{1}{2}°$ on June 21 to $-23\frac{1}{2}°$ on 21st December

* More strictly for the level at which the calibration is made.

purchase are those with Zr and Ti cathodes manufactured by the Westinghouse Electric and Manufacturing Company, U. S.A. The shape of these cells unfortunately is such that there is no way of using them so that the cathode can receive radiation from all portions of the sky and in such a way as to similate the radiation which would fall on a small horizontal surface. In fact certain portions of the sky will have an exaggerated effect. Moreover, the anode of this type of cell casts a shadow on the cathode surface. The U.S. Bureau of Standards (6) working in collaboration with R. Cashmere of the Northwestern University, Evanston, Illinois, was able to produce for the purpose special photo-cells which had a horizontal cathode area unaffected by anode shadow and quite ideal for the measurement of sun and sky radiation.

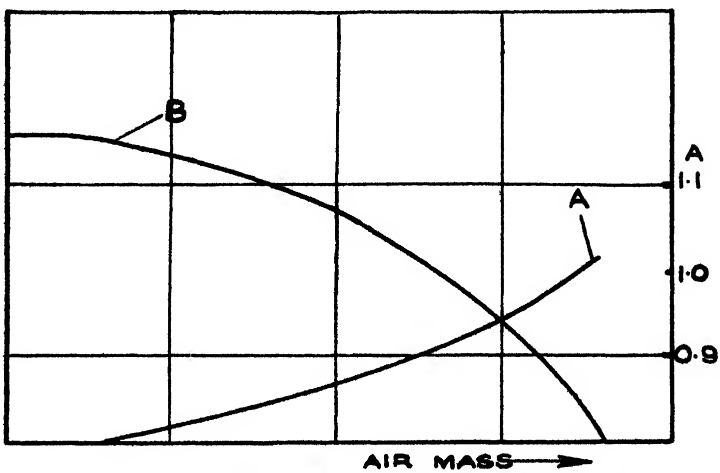


FIG. 2.

As our Scientific Liaison Officer in Washington has not been able to secure copies of these special photo-cells despite repeated efforts, we have endeavoured to eliminate the necessity for such special equipment, but without success.

Experiments conducted at Dominion Physical Laboratory, for example by G. E. K. Thompson, have shown that it is not possible to obtain a perfectly diffusing layer that would act as a flat receiving surface and enable the Ti and Zr photo-cells to sample the radiation transmitted by the diffuser. Trials were made by E. O. Hall at Dominion Physical Laboratory of a "photometric cube" constructed of aluminised glass walls, but the absorption of aluminium for ultra-violet radiation caused too great a reduction in intensity to make this method feasible. Again considerable thought has been given by F. F. Evison to the idea of scanning the sky (7). This idea is considered feasible but expensive compared with the use of a flat cathode photo-cell. Indeed full plans have been drawn up for the construction of a device to scan the sky and record ultra-violet radiation using a Ti photo-cell. No constructional work has, however, been proceeded with.

Regarding the circuit to be used in conjunction with the photo-cell this can be said to have been satisfactorily developed (8). It does represent some advance on circuits usually employed in that a recording of the ultra-violet radiation intensity can be obtained as well as the integrated count of radiation. Fig. 3 shows a typical record in which curve A is produced by a total solar radiation thermopile and curve B produced coincidentally by the Dominion Physical Laboratory ultra-violet meter. The circuit diagram given in (8) has been somewhat modified by Mr. R. L. Closs and the latest circuit is reproduced in Fig. 4. Quite early in our investigations it was discovered that the quartz envelope of the Ti or Zr photo-cells absorbed a layer of moisture, the conductivity of which rendered the meter quite unreliable. It could, however, be dissipated by placing the photo-cell in front of a heater or drying the air in contact with the cell. It is our practice, therefore, to mount the photo-cell in an enclosed space dried by silica gel. Radiation gains access to the cell via a translucent quartz window, this being our only means of sampling radiation from the whole sky. Translucent quartz, however, is by no means a perfect diffuser.

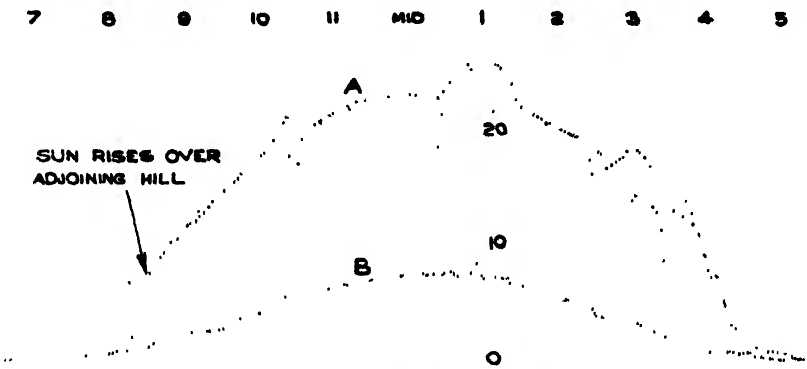


FIG. 3 — A. TOTAL SOLAR RADIATION
B. ULTRA-VIOLET RADIATION FROM SUN AND SKY (<3150Å)

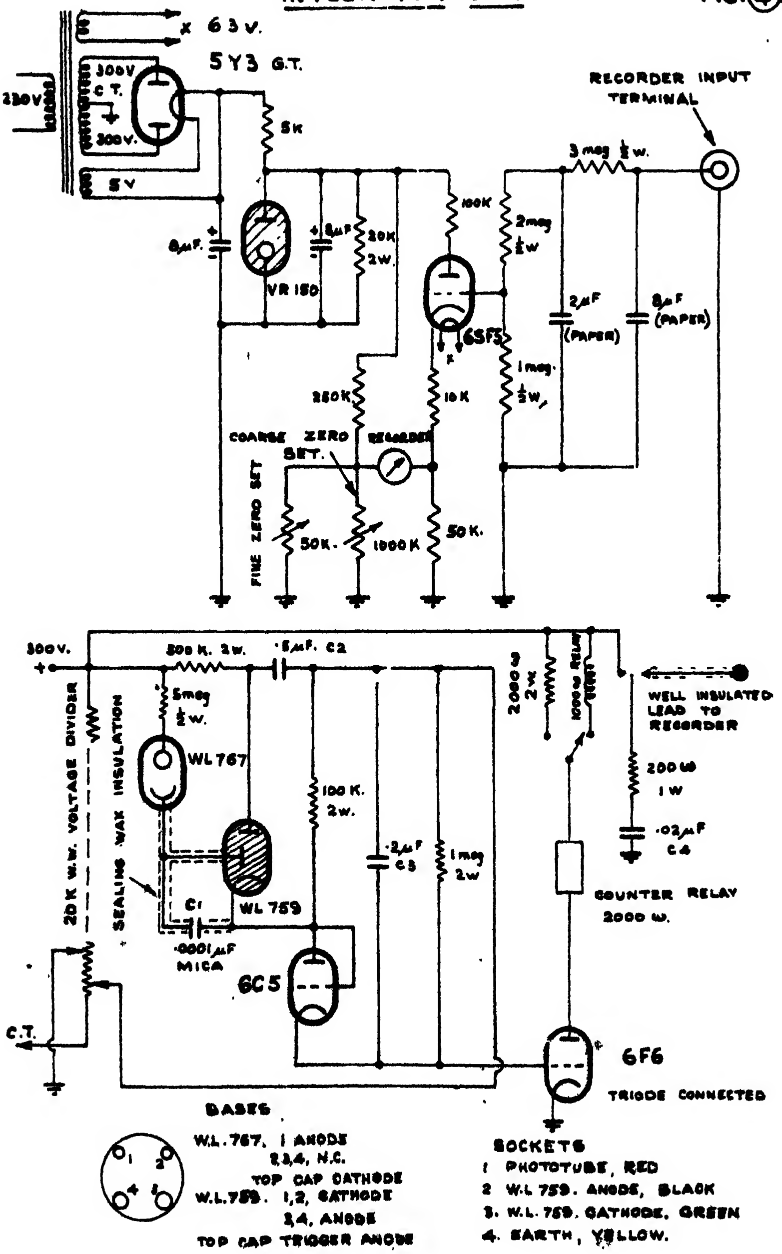
COMPARISON OF ULTRA-VIOLET RADIATION AT DIFFERENT STATIONS IN NEW ZEALAND

It will be evident from what has been stated above that if only comparative and not absolute measurements of solar plus sky ultra-violet radiation are required at a given air mass then there is no need to calibrate the photo-cell or photo-cells employed nor to determine their relative response curves. In the absence of a calibration we would not be able to relate meter readings for different air masses but only meter readings for the same air mass. If the ratio of the meter readings of two photo-cells were plotted against air mass, when the cells were exposed simultaneously at the same site, then a comparison curve such as A in Fig. 2 could be drawn which would enable us to compare the intensities of the ultra-violet radiation incident on the cells exposed at two different sites.

This prompted us to construct three ultra-violet meters in all. These meters will be intercompared at Wellington and subsequently placed one in the South Island, one at Wellington and the third in the north of the

North Island. These meters contain Zr cathode photo-cells with horizontal diffusing quartz windows; they will therefore not sample the sky radiation in the same way as radiation received on a horizontal surface. They will tend to exaggerate the value of radiation having a more vertical incidence. This is the best compromise which we can arrive at with the photo-cells available.

INTEGRATOR UNIT FIG. 4



So far as absolute measurements of solar and sky ultra-violet radiation are concerned, our thoughts are turning to the possibility of making the required special photo-cells at the Dominion Physical Laboratory Workshops. We would prefer, however, to be able to purchase these cells from a reputable overseas manufacturer. It is definitely considered that the problem of making these very difficult measurements at the ultra-violet end of the solar spectrum is worth investigation ; the need is for continuous daily recordings from the sky as well as the sun.

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ACTIVITY AT NGAURUHOE, APRIL - MAY, 1948

By L. R. ALLEN, New Zealand Geological Survey, Department of Scientific and Industrial Research, Rotorua

(*Received for publication, 15th December, 1948*)

Summary

Activity at Ngauruhoe during April-May, 1948, is described and supported by photographic documentation of the visible phenomena while the analysis of an ash sample collected during the eruption is presented in the appendix. A list of Ngauruhoe's historical eruptive dates is also given.

NGAURUHOE, 7,515 ft. in height, together with Ruapehu and Tongariro, is situated at the southern extremity of the most impressive volcanic district in New Zealand. As with the circum-Pacific chain of volcanic heights the prevailing rock is andesite and dates back to early Pleistocene times. Including the present eruption, twenty-three explosive outbursts varying both in length and violence have been recorded since 1839. The list is as follows :—

1839 (Bidwill, 1841); 1857 (Kerry-Nicholls, 1887); 1869 (?-70) (Hector, 1887); 6th July, 1881 (Pond and Smith, 1887 ; Kerry-Nicholls, 1887); February, 1892 (Thomson, 1926); 1905 (Marshall, 1934); February, 1907 (Marshall, 1908); 1907 (*Auckland Weekly News*, 8th November, 1907); March, 1909 (Johnston, 1909 ; Salmon, 1909); 1910 (Auckland papers, 19th October, 1910); 1911 (Marshall, 1934); May and August, 1913 (Thomson, 1926); November, 1917

(Thomson, 1926); 9-30th January and 22nd May, 1924 (Thomson, 1926); 16th April-June, 1926 (Jaggar, 1926); 4th March, 1928 (Grange, 1928); June and 7th December, 1934 (Marshall, 1934; Cobbe, 1935); September-October, 1940 (*The Dominion*, 22nd October, 1940); July, 1945 (*The Dominion*, 1st August, 1945); 30th April-May, 1948.

A flow of lava of the *aa* type is reputed to have taken place in 1869 (Hector, 1887) but this has not been definitely established. With this possible exception activity within historic times has been of the explosive type confined to the emission of steam, grey ash and blocks of augite—hypersthene andesite.

For the first time since 1945, when Ruapehu also was active, Ngauruhoe burst into eruption at 5.30 p.m. on 30th April, 1948. Observers at the Chateau state that activity commenced with the sudden eruption of clouds of black ash which, during the night, were associated with a red glow. Explosions were audible at the Pokaka Timber Company's Mill five miles north-west of the volcano. The activity increased during the night and, with incandescent ash rising 2,000 ft. above the summit, and extending one third the distance to the base, the mountain presented a most striking spectacle. Red-hot rocks were thrown 500 ft. into the air from the crater (see Fig. 1) and although at first these fell mainly on the south-west side, later the debris was scattered along the entire western half of the summit.

FIG. 1.—Simultaneous activity of Ngauruhoe (rt.) and Ruapehu (lt.), 1st May, 1948. Aerial view taken 40 m. to the South.

Photo: Evening Post.

Next day, 1st May, the activity continued with "shots" of ash and rocks at frequent intervals increasing in violence towards evening. At 11.20 a.m. Ruapehu sent up a single, majestic column of steam (see Fig. 2) which was observed clearly from Taupo. Local men who arrived at the Mangatepopo Hut (on the north-west side of Ngauruhoe) in the afternoon, and who spent the night there, add to our knowledge of the eruption by supplying the following facts :—

At 4.30 p.m., 1st May, local earthquakes occurred in the vicinity ($\frac{3}{4}$ mile from the base of the volcano) and ash and rocks were hurled

out. This was associated with "a roar like a mighty unmuffled exhaust." Marked activity continued and with the approach of darkness the summit was at times illuminated by incandescent material. At 11.00 p.m. electrical discharges caused a very brilliant display while the hut was again shaken. At 4.20 a.m. the next morning, 2nd May, the occupants were awakened by local ground movements and a loud roar emanating from the mountain, the summit of which was enveloped in "a dull-red glow." The duration of this more violent activity was about ten minutes. At 8.00 a.m. a particularly spectacular outburst took place accompanied by a heavy sharp rumble and, despite the daylight, a red glow covered the summit. Hot boulders with an estimated diameter of up to 20 ft. were observed falling and rolling down the north-west side of the mountain.

FIG. 2.—Ash and rocks being ejected from the crater of Ngauruhoe, 1st May, 1948. Note trails associated with some of the larger fragments.

Photo: N.Z. Aerial Mapping Ltd.

The writer arrived at the scene the preceding afternoon, 1st May, and although, as is evident from the above description, most of the activity was to the north-west of the volcano, much was to be seen from the Chateau side and similar outbursts were recorded.

On Sunday morning, 2nd May, the writer left the Chateau with a small party to ascend Ngauruhoe. Since daylight the volcano had been mushrooming-up columns of ash to a height of several thousand feet and according to Mr. R. H. Ward, a Taupo observer, who by virtue of the wind direction was better placed to observe heights, several shots between 8.12 a.m. and 8.30 a.m. rose to over 11,000 ft. At 10 a.m., while about three miles from the crater, the party witnessed several explosive phases at approximately five minute intervals. Despite the distance, boulders thrown out were readily seen and their size was estimated as approaching

that of a small house. These were also observed from the Chateau six miles distant. Loud noises like that of heavy, muffled artillery fire accompanied these outbursts although no earth tremors were felt.

FIG. 3.—Ngauruhoe. 1st May. General view looking north-east Paretetaitonga (Ruapehu) in foreground. Lake Taupo left background.

Photo: Blackmore's Air Services Ltd.

FIG. 4.—Ngauruhoe, 1st May, looking east. Ash cloud mushrooming-up from crater.

Photo: Blackmore's Air Services Ltd.

During the actual ascent of the mountain up the rift valley on the south-west side, activity continued fairly constantly with the emission of clouds of ash-laden steam punctuated by shorter, much more infrequent periods during which nothing but white steam was observed. No further noises were audible except near the summit when at times the high-pressure emission of gases and steam was coupled with a low steady swish lasting for a few seconds. Fine ash, lapilli, scoriaceous material and small boulders of andesite up to a foot in diameter were observed during the final 500 ft. climb to the crater lip.

DESCRIPTION OF CRATER

The crater (Figs. 5 and 6) appeared to be very similar to a photograph featured by Professor C. A. Cotton on p. 227 of his "Volcanoes as Landscape Forms" (1944). Well marked fumarolic activity was in evidence on the face of the higher cliffs to the east and the crater was divided into three unequal parts by the walls of the inner "nested" crater while the orifice itself occupied the north-west corner of the most southerly third. An outstanding difference, however, was the presence of vast quantities of rock and ash on the floor of the inner "nested" crater—so thick that the rim was almost obscured—and between the remains of this rim and the steaming cliffs (Fig. 6). The rubble rose to within about 20 ft. of the top of this latter. A descent to the rim of the inner crater was made but this was of short duration due to the acrid acid fumes.

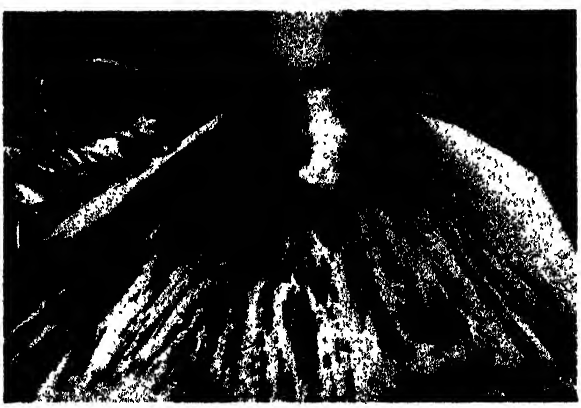

FIG. 5.—Ngauruhoe, 16th May, showing division of crater into three parts. Note steam rising prior to further ash eruptions.

The orifice, to which activity was confined, continued to belch forth huge quantities of ash-laden steam—light to dark-grey in colour—but at no time did it clear sufficiently for the interior to be seen. As had been observed earlier, outbursts were usually preceded by periods of relative quiescence while the emission of pure white steam usually foretold a particularly violent shot accompanied by hot rocks and ash. At 4.20 p.m. a most violent outburst took place preceded by a quiescent period when nothing but white steam was emitted. Without any warning and accompanied by a tremendous swish a huge volume of ash, steam and rock was hurled out from the orifice. Some rocks fell back into the vent, a few landed on the floor of the crater while the majority described graceful arcs and, trailing tails of "steam" behind them, descended

within and beyond the outside rim of the main crater at the north-west side. A mild trembling of the summit was felt. No lava flows associated with the present activity could be observed and the supposed lava flows during the hours of darkness were apparently merely hot rocks and ash tumbling down from the crater. Small flashes and sharp cracks sometimes accompanied the ascent of a " shot ". A noticeable feature, too, was the almost complete absence of either sulphurous fumes or deposited sulphur in, or adjacent to, the crater, although, as mentioned previously, acrid, acid fumes were present. Altogether almost two hours were spent on the summit and after collecting specimens of recent ash and ejecta the return journey was commenced.

FIG. 6.- Ngauruhoe, 1st May. Close up of crater. Ash cloud rising from vent to left and fumurolic activity at cliffs to right Note faintly discernible lip of inner " nested " crater in centre and vast quantities of ejecta on crater floor.

Photo: Blackmore's Air Services Ltd.

That night, 2nd-3rd May, was the last occasion upon which the emission of incandescent material was observed by the writer and during the following week the volcano continued to " smoke " quietly. The latest report to hand (*Auckland Star*, 11th September, 1948) indicates that quantities of ash and steam are still being thrown out at irregular intervals.

No increased activity was reported at Ketetahi hot springs on the slopes of Tongariro, although the writer was informed by local observers that more steam than normal issued from the craters on Tongariro during the early stages of the eruption. Seismic activity in New Zealand was normal both preceding and following the outburst.

The eruption of 1948 appears to have been very similar to those previously described.

Samples of rock and ash from the May activity were forwarded to the Dominion Laboratory for analysis and it is hoped to publish the results at a later date.

ACKNOWLEDGMENTS

Thanks are due to Mr. G. L. Adkin, New Zealand Geological Survey, Wellington, for valuable assistance in compiling the list of eruptive dates.

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APPENDIX

NGAURUHOE ASH ANALYSIS*

A sample consisting of 35 g. of gravelly material was obtained after soaking the original sample of ash for three weeks in 350 ml. of water and filtering. From the residue left after the filtration, partially dried, a sample was prepared and analysed for the main constituents.

The results were as follows:

SiO_2	57.09
Al_2O_3	14.44
Fe_2O_3	2.95
FeO	5.08
TiO_2	0.90
MgO	3.98
CaO	5.19
Na_2O	2.16
K_2O	1.20
MnO	0.10
P_2O_5	0.17
BaO	0.04
SO_3	2.46†
Cl	0.07
CO_2	trace
H_2O+	2.36
H_2O-	1.92
	100.11

* Kindly supplied by the Dominion Laboratory.

† This is total sulphur, determined by the fusion method and expressed as SO_3 (equivalent to 0.985 per cent. S). Of this only 0.15 per cent. SO_3 could be extracted by boiling the sample with water, whilst a further 1.25 per cent. SO_3 could be extracted by means of boiling dilute hydrochloric acid (1 acid : 5 water),—but no further amount by means of ' aqua regia '. No evidence of the presence of iron pyrites in the sample was obtained in the course of the analysis. As the presence of pyrites and of free sulphur thus seems to be precluded, it is possible that, apart from the presence of gypsum, anhydrite, and other acid-soluble sulphates, very basic sulphates, such as Alunite, $K_2Al_6(OH)_{12}(SO_4)_4$, which are said to be unattacked by hydrochloric or nitric acid, may be present.

NOTE ON INVESTIGATION ON THE USE OF SUPERSONIC PULSES FOR MEASURING THICKNESS

By J. TEMPLETON, Dominion Physical Laboratory, Lower Hutt

(*Received for publication, 6th October, 1948*)

DETAILS are given in D.P.L. Report No. 8/7/53 of the work carried out at the Dominion Physical Laboratory from July, 1947, to January, 1948, in the attempt to evolve a method for measuring the thickness of concrete by supersonic pulses.

The method tried was to inject into the face of a concrete layer short bursts of supersonic energy in the hope that they would be reflected from the back surface of the layer with sufficient energy to be received again at the face. Measurement of the time elapsing between transmission and reception would then provide a direct measure of the thickness of the layer.

An X-cut circular quartz crystal of diameter 3.25 cm., having a frequency of 300 kc/s was chosen as the source of supersonic sound. Details are given of the crystal transducer which was designed so that the maximum amount of supersonic energy could conveniently be injected into a specimen under test.

All the initial work was carried out on a solid rod of mild steel in order that the electronic circuits could be developed to their optimum efficiency. It was found that supersonic waves could only be injected into the surface when the latter was ground flat and smeared with an even layer of a suitable conducting medium such as vaseline, oil or plasticine.

The transmitter generated damped bursts of high frequency oscillations at a repetition frequency of 50 p/s. The output stage consisted of a condenser discharging through a thyratron and shocking the crystal into oscillation. For maximum efficiency the crystal load was made purely resistive by neutralizing the self-capacitances of the transducer and leads with an inductance connected in parallel.

The receiver, which was fed from a transducer identical to that at the transmitter, was a conventional band-pass R.F. amplifier tuned to 300 kc/s with a gain of more than 100,000. The receiving transducer converted the supersonic signal from a compressional-wave disturbance to an electrical vibration by the converse piezo-electric effect. Amplified signals from the receiver were fed to the synchroscope and displayed as a steady image since its linear sweep was triggered 50 times per second by negative pulses, the phase of which could be varied with respect to the pulse from the transmitter. The trace on the synchroscope showed both the transmitted pulse and the echoes from the flaws in the metal or from the boundary surface.

Tests were carried out successfully on good supersonic conductors, such as metals and water, but it was found impossible with the above equipment to detect any reflections when the supersonic pulses were applied to the surface of specimens of concrete.

It was therefore concluded that with a frequency as high as 300 kc/s, it is not practicable to transmit supersonic sound through concrete and similar materials. Possible causes of failure are:—

(1) Unsatisfactory supersonic conduction between transducer and face of the specimen;

(2) All waves may be totally scattered by discontinuities, like pebbles, because the wavelength (0.6cm.) is of the same order as the size of the obstacle;

(3) The supersonic energy generated may not be sufficient.

It should be noted that, even though the equipment could detect flaws in metals, it is preferable to use a frequency of several megacycles per second for flaw detection if fine resolution is required.

EFFECT OF FINAL VACUUM ON KICKBACK IN *PINUS RADIATA* AND *P. LARICIO* TREATED BY AN EMPTY-CELL METHOD WITH AN AQUEOUS SOLUTION

By K. M. HARROW, Plant Diseases Division, Department of Scientific and Industrial Research

(*Received for publication, 27th May, 1948*)

Summary

The effect on kickback of a vacuum of 20 in. Hg applied to *Pinus radiata* and *P. laricio* timber after pressure impregnation with an aqueous solution has been studied. Results showed that holding in vacuo for one hour produced a greater kickback than occurred in the same time without vacuum, but kickback was not complete. Twenty-four hours after impregnation, the kickback from boards which had been subjected to an hour's final vacuum was identical with that from boards allowed to drain at atmospheric pressure.

INTRODUCTION

A COMMON commercial practice when preserving timber by pressure impregnation is to remove excess solution from the timber by drawing a vacuum in the pressure cylinder following the emptying of solution after impregnation. The American Wood-Preservers' Association Manual of Recommended Practice (1948) states:—" After pressure is completed, the cylinder shall be emptied speedily of preservative, and a vacuum of not less than 22 inches at sea level created promptly and maintained until the wood can be removed from the cylinder free of dripping preservative."

Experience with the pilot pressure plant (Harrow, 1947a) suggested that this practice was not warranted; tests were, therefore, made using *Pinus radiata* and *P. laricio* to measure differences in kickback with and without final vacuum.

METHOD

Four groups of six *P. radiata* and three groups of six *P. laricio* boards 5 in. x 1 in. were used for the experiment. Immediately before treatment the boards of each group were cut to 8 ft. lengths by removal of at least 2 ft. from each end. Moisture content samples were taken from the off cuts and the air dry weight of each board recorded. Each group was treated separately with 2 per cent. aqueous boric acid at air temperature. For each charge the cylinder was filled with solution at atmospheric pressure and then a pressure of 200 lb./sq. in. rapidly applied. When gross absorption had ceased pressure was released, the cylinder emptied of solution and the boards taken out and weighed individually. Approximately 20 minutes elapsed between release of pressure and weighing. This weight will be referred to as " out of cylinder " weight.

Three boards in each group of six selected at random were put back into the cylinder immediately after weighing and subjected to a vacuum of 20 in. Hg for one hour. To prevent drying, the other three boards were held in a closed tank over water for the same period. Immediately

TABLE I. EFFECT OF A FINAL VACUUM OF 20 IN. HG FOR 1 HOUR ON KICKBACK RATIO (K.B.R.) OF *Pinus radiata* AND *P. laricio* AFTER 0-200 LB./SQ. IN. TREATMENT. (MEANS OF 12 AND 9 BOARDS RESPECTIVELY)

Treatment.	Air Dry Weight. (lb.)	Gross Absorption. (lb.)	Out of Cylinder.		After Treatment.		After 24 Hours.		Final.		Volume (Cu. Ft.)	Moisture Content (Per cent.)
			Wt. (lb.)	K.B.R.	Wt. (lb.)	K.B.R.	Wt. (lb.)	K.B.R.	Wt. (lb.)	K.B.R.		
P. radiata:												
Final Vacuum	9.65	10.35	17.35	0.26	14.43	0.54	13.69	0.61	13.48	0.63	0.308	20.0
No Vacuum	9.64	10.98	17.29	0.30	15.98	0.43	13.98	0.60	13.58	0.64	0.312	19.1
Standard Deviation of Mean Difference				0.034		0.032		0.019		0.017		
†				1.17		3.5*		0.53		0.59		
P. laricio:												
Final Vacuum	8.77	12.24	17.23	0.30	14.64	0.51	13.94	0.57	13.63	0.60	0.32	15.7
No Vacuum	9.11	12.11	17.53	0.30	16.31	0.40	14.59	0.54	14.18	0.57	0.325	15.5
Standard Deviation of Mean Difference				0.035		0.039		0.039		0.036		
†				—		2.8†		0.82		0.83		

* Significant at 0.01 level

† Significant at 0.02 level.

TABLE II. GROSS ABSORPTION, KICKBACK AND NET ABSORPTION IN GALLONS PER 100 SUPER FEET. CALCULATED FROM TABLE I

Treatment.	Gross Absorption.	Kickback.				Net Absorption.
		Out of Cylinder.	After Treatment.	24 Hours.	Final.	
P. radiata:						
Final Vacuum	28.0	7.2	15.1	17.1	17.6	10.4
No Vacuum	29.3	8.9	12.4	17.7	18.8	10.5
P. laricio:						
Final Vacuum	31.9	9.8	16.5	18.4	19.2	12.7
No Vacuum	31.0	9.4	12.6	17.0	18.0	13.0

after vacuum treatment was completed the six boards were weighed again individually and the "after treatment" weight obtained. All six were then placed in the closed tank for 24 hours and again weighed, the "24 hour" weight. Finally they were returned to the tank and weighed daily until constant weight showed that kickback had ceased.

Gross absorption of each group was expressed as a percentage of the sum of theoretical maximum absorptions of all boards in a group (Harrow, 1947b). This percentage was used to calculate the gross absorptions of each board, assuming that the figure for each board was the same as that of the group. This assumption is justified by the data on gross absorption percentages that have accumulated.

The kickback ratio of each board was calculated from the four weights using the following formula:—

$$\frac{\textit{Gross Absorption—(Out of Cylinder Weight—Air Dry Weight)}}{\text{Gross Absorption}}$$

RESULTS

Mean weights and kickback ratios at different periods after impregnation are given in Table I.

Table II shows gross absorption, kickback at different periods and final net absorption in gallons per 100 ft. B.M., all of which were calculated from the means in Table I.

DISCUSSION

From Table I it is seen that, initially, kickback was rapid, almost half occurring in the first 20 minutes after release of pressure. Application of an hour's final vacuum of 20 in. produced a significant increase in kickback ratio compared with no final vacuum, but after 24 hours ratios were virtually the same and remained so when kickback was complete.

Thus use of vacuum treatment after impregnation merely accelerates kickback. Advantages are rapid recovery of a small quantity of solution. Against this must be set the time wasted by a charge remaining an extra hour in the cylinder. As an efficient pressure plant should be capable of impregnating a change of pinus timber in one hour, it is very doubtful if the use of a plant for a final vacuum treatment is sound economically. Instead a covered draining platform capable of holding one day's output should be provided, where treated timber can stand for 24 hours after impregnation.

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CHEMICAL PROPERTIES OF TWO NEW ZEALAND BENTONITES

Recently two samples of bentonite (1), one from Porangahau, Hawke's Bay and the other from Oaro, Marlborough, were examined to estimate their value as a base exchange medium for synthetic pot soils. The former contained 15.6 per cent. calcium carbonate, had a base exchange capacity* of 43.7 m.e. per cent. and contained 11.4 m.e. per cent. of exchangeable sodium. A leaching with N-calcium chloride showed that the sodium could readily be removed. However, for pot experiments it would also be necessary to remove the calcium carbonate and as this would probably be impracticable without special equipment the Porangahau material seemed unsuitable for our purpose.

The Oaro sample had a base exchange capacity of 74.0 m.e. per cent. and contained 36.6 m.e. per cent. of exchangeable calcium. There was no exchangeable sodium and no free calcium carbonate. The introduction by leaching of, say, 18 m.e. per cent. of magnesium and 4 m.e. per cent. of potassium would bring the base saturation to 80 per cent. and provide the basis for a very useful standard soil.

In the course of this work, it was found possible, by normal base exchange methods, to improve the swelling properties of both samples. These properties which are estimated from the magnesium oxide test (2), in practice largely determine the commercial value of the mineral. The Porangahau material had a swelling co-efficient of 98. Leaching with sodium chloride increased this to 100 and leaching with calcium chloride reduced it to zero. The Oaro sample which was non-swelling was leached with sodium chloride. This converted it into a high grade, 100 per cent. swelling, bentonite.

The Porangahau deposits are large (3) and for uses requiring better swelling properties and in which calcium carbonate is not detrimental it may be possible to form the sodium clay at reasonably low cost by leaching with sodium chloride. Elaborate treatment would not be practicable as bentonite is essentially a low cost product. The Oaro deposits which outcrop in the valley of the Mikonui stream are comparatively small and although quantities sufficient for the pot work done in New Zealand should be readily obtainable, larger scale commercial development is not possible.†

Results from the above work suggest that considerable improvements may be made in some lower grade bentonites by a reasonably simple dressing process and therefore if any such ores have been condemned in the past, because of inadequate swelling properties, they should be re-evaluated with this process in mind.

R. B. MILLER

27th July, 1948.

Soil Bureau,
D.S.I.R.,
WELLINGTON.

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* Found by leaching with N-ammonium acetate at pH7, followed by 80 per cent., slightly ammoniacal, ethyl alcohol.

† Personal communication from H. E. Fyfe, Geological Survey.

SCIENTIFIC NOTES.

INTERNAL PARASITES OF HORSES IN NEW ZEALAND.

It is desirable that the species of internal metazoan parasites of the horse in New Zealand should be known. To this end a limited amount of material from the Manawatu district was examined post mortem. As there appears little immediate prospect of continuing the investigation, the decision has been made to publish the results as they stand.

The writer is indebted to Dr. A. O. Foster of the Bureau of Animal Industry, U.S. Department of Agriculture, Washington, D.C. for named specimens, which facilitated the process of identification. In this connection Baylis (A Manual of Helminthology, Medical and Veterinary, 1929) was an additional aid.

		Species Found
Class	Cestoda	
Family	Anoplocephalidae	*Anoplocephala perfoliata* (Goeze, 1782)
Class	Nematoda	
Family	Strongylidae	*Strongylus edentatus* (Looss, 1900) *S. equinus* (Mueller, 1780) *S. vulgaris* (Looss, 1900) **Triodontophorus serratus* (Looss, 1900) **Oesophagodontus robustus* (Giles, 1892) *Cylicostomum coronatum* (Looss, 1900) *Cylicocercus catinatus* (Looss, 1900) *C. goldi* (Boulenger, 1917) *Cylicostephanus calicatus* (Looss, 1900) *C. minutus* (Yorke and Macfie, 1918) *C. longibursatus* (Yorke and Macfie, 1918) *Cylicocyclus nassatus* (Looss, 1900) *C. insigne* (Boulenger, 1917)
Family	Oxyuridae	**Oxyuris equi* (Rudolphi, 1803)
Family	Ascaridae	*Parascaris equorum* (Goeze, 1782)
Family	Spiruridae	**Habronema megastoma* (Rudolphi, 1819)
Class	Insecta	
Order	Diptera	
Family	Oestridae	*Gastrophilus intestinalis* (de Geer, 1776) **G. nasalis* (Linné, 1761) **G. haemorrhoidalis* (Linné, 1761)

Species marked with an asterisk are those which Dr. C. S. M. Hopkirk, formerly of the Wallaceville Veterinary Laboratory, has indicated by private communication that he has found, but were not present in material examined by the writer.

J. H. Tetley.

Massey Agricultural College,
Palmerston North.
3rd May, 1948.

PROCEEDINGS OF THE SEVENTH PACIFIC SCIENCE CONGRESS (New Zealand) 1949

The Organizing Committee proposed to publish the Proceedings of the Seventh Pacific Science Congress in single divisional or in appropriately grouped divisional volumes, and to offer single volumes as well as sets for sale.

No decision can yet be made as to the grouping of these volumes, or of price, but something of the following order may eventuate:

Volume			
I	General Proceedings, Narrative, Representation, Attendance, Research Plan Report	150 pp.	7/6d.
II	Geology, Geophysics and Volcanology -	600 pp.	28/6d.
III	Meteorology and Oceanography - -	400 pp.	20/-
IV	Zoology - - - - -	550 pp.	26/-
V	Botany, and Soil Resources Agriculture and Forestry - - - -	550 pp.	26/-
	Or V Botany - - - -	250 pp.	11/6d.
	VI Soil Resources, etc. - -	300 pp.	14/6d.
VI	Anthropology, Public Health and Nutrition;		
Or			
VII	Social Sciences - - - -	550 pp.	26/-

It will be realized that the larger the initial order for printing, the lower the cost of individual volumes will be; early registration with SECRETARY-GENERAL, BOX 27, NEWMARKET, AUCKLAND, S.E.1, will therefore ensure a copy being available and contribute to lowering the cost.

It is hoped to complete the printing by MARCH 1950.

It is emphasized that the above grouping and size of volumes are at the planning stage only, and the prices mentioned are, at the best, tentative.

THE NEW ZEALAND
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Editor: N. A. Marris, M.Sc.,B.Com. (Assistant Editor: M. O'Connor, M.Sc.) Department of Scientific and Industrial Research, Wellington

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A NEW METHOD OF MEASURING POTENTIALS OF POLARIZED ELECTRODES IN SOIL CORROSION CELLS

By W. NEIGHBOURS (late of Radio Development Laboratory, Dept. of Scientific and Industrial Research, Wellington)

(*Received for publication, 15th February, 1948*)

Summary

A method of interrupting the current through a soil corrosion cell and of measuring the potentials of the polarized electrodes during the period of interruption is described. An electronic circuit is used to interrupt the current and the potential across the cell at interruption is balanced against a known potential, an oscilloscope being used as a null indicator.

INTRODUCTION

For soil corrosion investigations being carried out at the Soil Bureau of the New Zealand Department of Scientific and Industrial Research, a method designed by Hickling (1) and applied by Denison and Darnielle (2) (3) was tried, but it was felt that some improvements could be made in the technique of measurement by using a visual method with oscilloscope presentation rather than the aural method of the Hickling meter. A circuit was accordingly developed along these lines and has proved to be satisfactory in the measurement of potentials of soil corrosion cells.

GENERAL DESCRIPTION OF METHOD

The new method is shown in the block diagram, Fig. 1. A is a sharp trigger pulse generator using a free running multivibrator circuit. The output from the master trigger is connected to the pulse shaping multivibrator B which operates only when a trigger is received from A. The output from B, which consists of a negative pulse of the desired interruption period and about 200 volts in amplitude, is used to control the rest of the apparatus consisting of the switching tube F, the time base generator C, and the time marking oscillator E. The negative pulse from B is applied to the switch tube F and this effects a complete interruption of the current from the power supply K to the corrosion cell G. The amplitude of the current through the cell is controlled by adjusting the grid bias of the switching tube and the negative voltage pulse causing interruption is superimposed on this average bias. The sweep time base C deflects the oscilloscope beam from left to right at a constant rate during the interruption period, thus providing the horizontal component

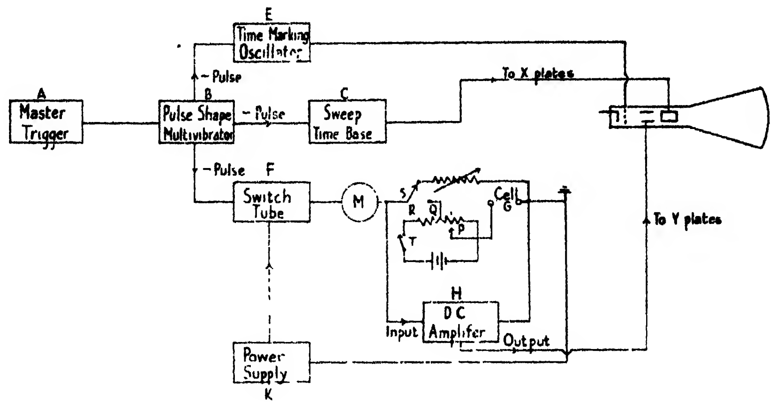

Fig. 1 Block diagram showing new method for Denison Cell Test

in the visual presentation. The time marking oscillator E is quiescent while current is flowing through the soil cell, but oscillates during the period of interruption, i.e., while the negative impulse from B is received. The output from this oscillator is applied to the grid of the cathode ray tube resulting in changes of intensity of the beam at the frequency of the oscillator and thus providing marks as the beam is being deflected and enabling the time of interruption to be quickly and accurately determined.

The potential, during the period of interruption, across the cell and the potentiometer (connected in series) is amplified by the D.C. amplifier H and applied to the Y or vertical deflecting plates of the cathode ray tube.

When a measurement is being taken the switch S, as shown in Fig. 1, is used to change from the cell and potentiometer in series to a resistance of approximately the same value as that of the cell. The vertical height of the horizontal trace on the screen is an indication of the potential between the point R and earth during interruption of the current. When the current is passed through the resistance there is no polarization and so the potential at interruption is zero, but when the current is applied to the cell and potentiometer in series the resultant potential at interruption is the potential of the cell and that across PQ. If P is varied so that the position of the trace on the oscilloscope is the same whether the resistance or the cell and potentiometer are in the circuit then the potential across PQ (which is known) must be equal and opposite to the polarization potential of the soil cell. Thus the oscilloscope is used as a null indicator, and the potential at interruption is read off directly in terms of the back voltage introduced by the calibrated potentiometer.

DETAILED DESCRIPTION OF CIRCUIT

The circuit is shown in detail in Fig. 2. V_1 is a double triode arranged as a free running multivibrator which, due to the blocking effect of the high impedance cathode circuit in the second section and the

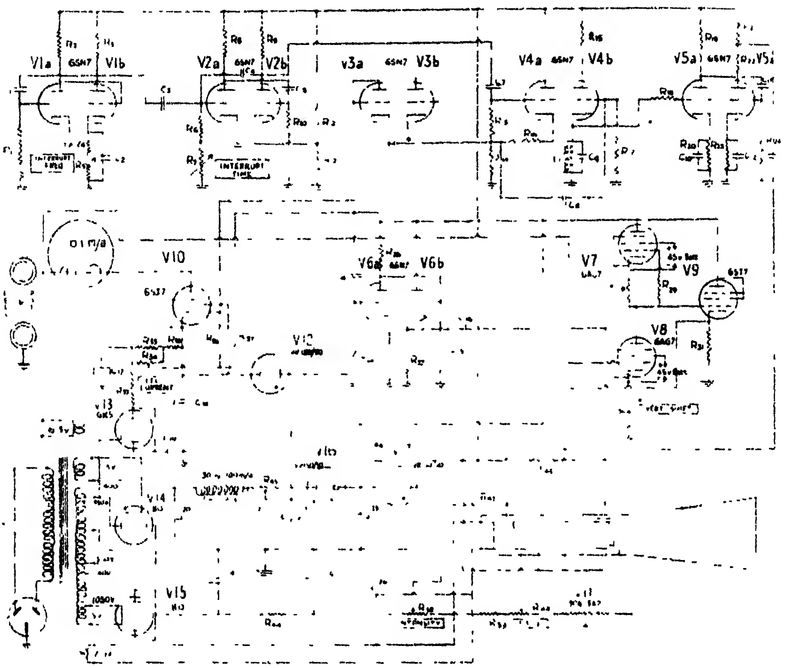

Fig. 2 New Circuit for Denison Cell Test

Resisters				Condensers			
$R_3, R_{10}, R_{24}, R_{26}, R_{27}, R_{39}, R_{44}$	250,000 ohms, 1w	R_{32}	10,000 ohms 3w	$C_1\ C_2$	0·01 mfd. 600v	C_{19}	1 mfd. 600v
R_1	100 000 ohms, 1w	R_{35}	500 ohms 1w	C_3	100 pfd. 500v	C_{20}	16 mfd. 500v
R_2, R_{12}, R_{13}	10,000 ohms, 1w	R_{41}	2 megohms, 2w	C_4	500 pfd. 500v	C_{21}	8 mfd. 450v
R_4	3 megohms 1w	R_{42}	1 megohms, 1w	$C_5\ C_{10}\ C_{11}\ C_{16}$	0·05 mfd 600v	C_{23}	8 mfd. 250v
R_6, R_8, R_{18}, R_{17}	50,000 ohms, 1w	R_{45}	5000 ohms, 25w voltage divider tapped at 300V	$C_6, C_7\ C_8, C_{14}$	0·1 mfd. 600v	C_{24}, C_{25}	1 mfd. 2kv
$R_8, R_9, R_{14}\ R_{21}$	25 000 ohms, 1w	Potentiometers		$C_9\ L_1$	Resonant at 10000 c/s	C_{26}	0·25 mfd 400v
$R_{15}, R_{17}, R_{19}, R_{20}\ R_{28}, R_{44}$	500,000 ohms, 1w	R_5	2 megohms	C_{11}	50 pfd. 500v		
$R_{16}\ R_{20}, R_{25}, R_{30}\ R_{33}$	2,000 ohms, 1w	$R_7\ R_{40}$	500,000 ohms	C_{13}	0·01 mfd. 2 kv		
R_{22}	5 000 ohms, 1w	R_{38}	100 ohms	C_{15}	0·004 mfd. 500v		
$R_{37}\ R_{43}$	15000 ohms, 1w	R_{34}	5000 ohms	C_{17}, C_{22}	16 mfd. 450v		
R_{29}	100 ohms, 1w	R_{36}	100,000 ohms	C_{18}	8 mfd. 450v		

direct coupling between the plate of the first section and the grid of the second, produces a short trigger pulse which is used to trigger V_2. V_2 is a multivibrator with the second section biassed beyond cut-off so that this stage is normally quiescent. The cathode of the second section of V_2 is taken to a tap on a potential divider between B+ and earth and the grid leak is taken to ground giving a negative bias to this section of approximately 25 volts, sufficient to cut off this side completely. The first section of V_2 is normally conducting as both cathode and grid resistor are returned to ground. Thus there is a low voltage on the plate of V_2a due to the drop across the plate resistor, and the anode of V_2b is at full H.T. because this side is cut off. The short negative trigger coming from V_1 is applied to the grid of V_2a and is of sufficient amplitude to cut this section off completely. The plate voltage now rises on V_2a and this rising wave-front is applied to the grid of V_2b via the resistance capacity coupling. Thus the grid of V_2b rises above the cut-off point and V_2b commences to conduct. The plate voltage on V_2b starts to fall because of the IR drop in the plate resistor and this falling wave-front is communicated back to the grid of V_2a. In this way a

cumulative action is started and the sections of V_2 rapidly reverse roles, V_2a being cut-off and V_2b being in a conducting state. The negative charge on the grid of V_2a then leaks away through the grid resistor, and after a period, depending on the time constant of the grid resistor and the coupling condenser to the plate of V_2b, V_2a again commences to conduct. The above action is now reversed and the stage then reverts to its normal quiescent state to await the next pulse from V_1 which is much shorter than the smallest desired time of cell current interruption. Therefore, at the moment of the trigger there is a positive going pulse on the plate of V_2a and a negative going pulse on the plate of V_2b, both of which are of the same duration. This pulse time, which is the time of interruption of the cell current, is controlled by means of the variable resistor in the grid circuit of V_2a from about 10^{-4} to 10^{-8} seconds. The frequency of interruption, or the frequency of triggering by V_1 is controlled by the variable resistor in the cathode circuit of V_1b.

The negative going pulse on V_2b is then fed to the first section of V_4 which is arranged as a cathode follower buffer stage, and from the cathode of this stage the negative pulse of about 100 volts is used to control the rest of the circuit.

V_{10} is a pentode which controls the current through the soil cell. 150 volts negative is fed to the cathode of this tube and the plate goes to ground through the milliameter and the soil cell in series. The standing current is controlled by varying the grid bias on V_{10} by means of the potentiometer R_{34}. This current is completely interrupted by the negative pulse from V_4a through the diode V_3a. The purpose of this diode is to eliminate the positive kick-back which would otherwise appear after the negative pulse on the grid of V_{10}, due to the coupling condenser. The interruption pulse by this method approximates the ideal rectangular form, so effecting complete cut-off for the pre-determined time.

At the same time that the current is interrupted in V_{10}, V_6a is also cut off and the condenser C_{15} charges up towards B+. This rising voltage, after passing through the cathode-follower section V_6b is applied to the X plates of the oscilloscope and causes the beam to move from left to right. The distance that the beam traverses depends on the time of the master negative pulse, i.e., the horizontal sweep occurs during the period of interruption.

Section b of V_4 normally has its grid at earth potential and is therefore conducting. The plate current of this tube passes through an LC circuit tuned to 10,000 cycles per second. The master negative pulse cuts this stage off also, and the current in the tuned circuit dies away as a train of damped oscillations at its resonant frequency. This train of oscillations lasts for the duration of the negative pulse, i.e., during the interruption period, and after amplification and limiting at V_5a and b where all the oscillations are brought to the same level the train is applied to the grid of the cathode ray tube, and as the sweep moves from left to right a series of timing marks (one for each 10^{-4} sec.) are described which serve to calibrate the duration of the negative pulse and consequently the time of interruption of the cell current.

V_7, V_8 and V_9 constitute a D.C. amplifier and cathode-follower output stage which is connected to the Y plates of the cathode ray tube, and the input of which is across the soil cell and external potentiometer. Therefore the potential across the cell and potentiometer during interruption governs the height of the sweep of the scope beam while the duration of interruption controls the length of sweep in the horizontal direction.

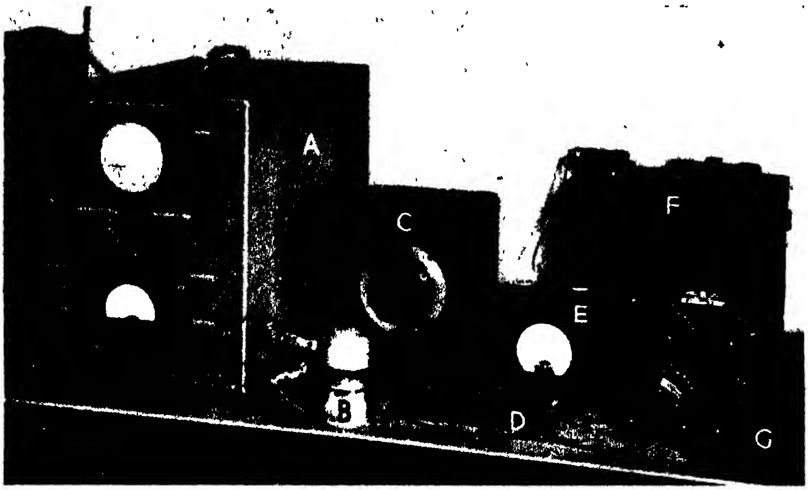

FIG. 3 Apparatus for Denison Cell Test :

A Circuit shown diagrammatically in Fig. 2.
B. Soil cell
C Potentiometer
D Switches (2) shown as S and T in Fig. 1
E Voltmeter across battery F.
F. Battery across potentiometer C
G Resistance box (0-10,000 ohms)

FIG 4.—Potentiometer used in Denison Cell Test.

CONSTRUCTIONAL DETAILS

The circuit as shown in Fig. 2 was enclosed in a case 44 cm. long, 25 cm. wide, and 30 cm. high, which is shown together with the rest of the apparatus used in the test in Fig. 3. The soil cell is normally enclosed in a sealed glass jar even while under test, in order to minimize moisture loss, but the jar is omitted in Fig. 3 for the sake of clearness. The cell is made of transparent acrylic plastic in three pieces and is the same in principle as that described by Denison and Darnielle (2). The construction of the potentiometer used to balance the potential across the cell is shown in Fig. 4. It consists of a machined frame, the sliding part of which contains a bakelite drum on which is wound ten turns of resistance wire. This part is arranged to slide on two supports in the fixed part of the frame, one of which can be seen on the right in the photograph. A screw thread on the dial shaft engages in a threaded hole in the centre of the sliding drum. This thread is arranged to have the same pitch as the resistance winding. An extension on the threaded shaft at the rear of the potentiometer carries the wiping arm shown in the photograph. Thus as the wiping arm revolves the drum slides in or out according to the direction of rotation keeping the consecutive turns of the coil under the arm. The wiping contact is an inclined copper roller. An engraved indicating rod which projects through the front of the case shows which turn of the coil is under the arm.

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A CLASSIFICATION OF NEW ZEALAND COAL

By M. T. TE PUNGA, Geology Department, Victoria University College, Wellington.

(Received for publication, 22nd September, 1948)

Summary

A classification of New Zealand coal according to the A.S.T.M. scheme is given.

As the properties of the constituents of coal and the chemical treatments for separating spores from coal both vary with the rank, a classification of New Zealand coals by rank is essential if the constituents and spores are to be studied.

The classification recommended by the American Society for Testing Materials (Moore, 1940, p. 131), and approved by the United States Bureau of Mines, can be used conveniently for classifying New Zealand coals.

In the Dominion Laboratory Coal Survey Report No. 80 (see Table I) a series of New Zealand coals has been broadly classified into four main groups. Table II gives the A.S.T.M. classification of coal by rank. The present classification of New Zealand coals (Table III) is based on the A.S.T.M. scheme using the figures given in Table I, and it is considered that this classification is less difficult to apply than Seyler's classification as modified by Evans (1924).

The calculations were made by employing the "moist" basis approximation formulae (Moore, 1940, p. 133) as follows:

1. Dry, Mm-free F.C. $= \dfrac{\text{F.C.}}{100 - (\text{M} + 1.1\ \text{A} + 0.1\ \text{S})} \times 100$
2. Dry, Mm-free V.M. $= 100 -$ Dry, Mm-free F.C.
3. Moist, Mm-free B.Th.U $= \dfrac{\text{B.Th.U}}{100 - (1.1\ \text{A} + 0.1\ \text{S})} \times 100$

where Mm = mineral matter, F.C. = percentage of fixed carbon, V.M. = percentage of volatile matter, M = percentage of moisture, A = percentage of ash, and S = percentage of sulphur. In the above formulae the percentage of fixed carbon + volatile matter + moisture + ash = 100.

It should be noted that the A.S.T.M. classification of coal by rank is a refined and rigid division of coals into a series of groups that are arranged in order in accordance with the degree of alteration of the coals in the natural sequence from lignite to anthracite. The classification represents the result of ten years of intensive work by individuals and organisations representing all fields of interest in coal. Hendricks has emphasized the importance of this classification as a basis for disposing of problems of the rank of coal (Hendricks, 1938).

TABLE I. ANALYSES OF REPRESENTATIVE NEW ZEALAND COALS (AIR-DRIED SAMPLES) (Dominion Laboratory Coal Survey Report No. 80. 15/7/41)

Class and Locality	Moisture	Volatile matter	Fixed Carbon	Ash.	Sulphur.	B.Th.U. per lb	Crucible Swelling No
Super-Bituminous –							
Paparoa No 1 seam	0.9	17.4	78.5	3.2	0.28	15,040	5
Paparoa No 2 seam	0.7	24.4	73.1	1.8	0.34	15,300	9++
Bituminous							
Millerton	1.0	37.2	60.4	1.4	4.15	14,540	9+
Denniston	2.0	39.9	55.4	2.7	2.27	14,290	7½
Stockton	2.3	38.4	57.5	1.8	4.70	13,640	7½
Liverpool	1.1	34.6	59.8	4.5	0.35	14,570	9++
Dobson	0.8	42.0	51.8	5.4	1.86	14,080	9+
Wallsend	0.7	40.0	52.5	6.8	2.44	13,960	9+
Strongman	6.3	40.4	51.1	2.2	0.26	12,940	3½
Blackball	4.3	49.8	45.1	0.8	5.24	13,790	7½
Blackburn	2.3	43.1	53.4	1.2	4.99	13,480	5½
Murchison	4.5	42.3	47.4	5.8	2.86	13,400	2
Sub-Bituminous –							
Hikurangi	5.3	43.1	45.8	5.8	5.53	12,070	1½
Reefton No 2 seam	7.0	47.2	43.6	2.2	5.12	(12,100)	1½
Reefton No 4 seam	13.6	39.6	45.2	1.6	1.41	11,170	N C.
Glen Afton	16.1	38.4	42.1	3.4	0.29	10,650	N.C.
Rotowaro (Taupiri)	16.3	39.4	40.9	3.4	0.18	10,190	N C.
Pukemiro	16.3	39.7	42.4	1.6	0.22	10,490	N C
Wilton	12.9	46.0	38.4	2.7	0.54	11,150	N.C.
Mangapehi	16.6	37.4	39.6	6.4	0.75	9,500	N.C.
Tatu	11.1	45.2	37.9	5.8	5.11	10,450	N C.
Linton	16.2	36.7	44.6	2.5	0.20	10,780	N.C.
Wairaki	16.6	33.0	43.5	6.9	0.18	9,880	N.C.
Kaitangata	17.6	36.3	39.9	6.2	0.20	9,740	N C.
Lignites :—							
Charleston	23.7	41.8	30.8	3.7	5.71	9,300	N.C.
Mt. Somers	18.4	37.4	35.5	8.7	2.46	(8,500)	N C.
Klondyke (North Canterbury)	22.5	32.9	39.9	4.7	0.44	9,180	N.C.
Mataura	29.3	37.1	27.7	5.9	0.50	7,340	N.C.
Bannockburn	30.3	39.3	23.3	7.1	0.42	7,780	N.C.
Omokoroa (Tauranga)	21.9	39.6	31.0	7.5	0.41	7,480	N.C.

TABLE II. A.S.T.M. CLASSIFICATION OF COAL BY RANK*

F.C. = fixed carbon. V.M. = volatile matter. B.Th.U. = British thermal units.

Class.	Group.	Limits of fixed carbon or B.Th.U. Mineral-matter-free Basis	Requisite physical properties.
i. Anthracitic	1. Meta-anthracite	Dry F.C., 98 per cent. or more (dry V.M. 2 per cent. or less)	Non-agglomerating†
	2. Anthracite	Dry F.C., 92 per cent. or more and less than 98 per cent. (dry V.M., 8 per cent. or less and more than 2 per cent.)	
	3. Semi-anthracite	Dry F.C., 86 per cent. or more and less than 92 per cent. (dry V.M., 14 per cent. or less and more than 8 per cent.)	
ii. Bituminous**	1. Low-volatile bituminous coal	Dry F.C., 78 per cent. or more and less than 86 per cent. (dry V.M., 22 per cent. or less and more than 14 per cent.)	
	2. Medium-volatile bituminous coal	Dry F.C., 69 per cent. or more and less than 78 per cent. (dry V.M., 31 per cent. or less and more than 22 per cent.)	
	3. High-volatile A bituminous coal	Dry F.C., less than 69 per cent. (dry V.M. more than 31 per cent.); and moist B.Th.U., 14,000 or more.	
	4. High-volatile B bituminous coal	Moist‡ B.Th.U., 13,000 or more and less than 14,000 §	
	5. High-volatile C bituminous coal	Moist B.Th.U., 11,000 or more and less than 13,000 §	Either agglomerating or non-weathering¶
iii. Sub-bituminous	1. Sub-bituminous A coal	Moist B.Th.U., 11,000 or more and less than 13,000 §	Both weathering and non-agglomerating
	2. Sub-bituminous B coal	Moist B.Th.U., 9,500 or more and less than 11,000 §	
	3. Sub-bituminous C coal	Moist B.Th.U., 8,300 or more and less than 9,500 §	
iv. Lignitic	1. Lignite	Moist B.Th.U., less than 8,300	Consolidated
	2. Brown coal	Moist B.Th.U., less than 8,300	Unconsolidated

* This classification does not include a few coals which have unusual physical and chemical properties and which come within the limits of fixed carbon or B.Th.U. of the high-volatile bituminous and sub-bituminous ranks. All these coals either contain less than 48 per cent. dry, mineral-matter-free, fixed carbon or have more than 15,500 moist, mineral-matter-free B.Th.U. J. F. BARKLEY and L. R. BURDICK, (1937): "Curves for the classification of Coal," *U.S. Bureau of Mines, Information Circular 6933*, and (1938): *A.S.T.M. Standards on Coal and Coke, Rept. Committee D-5.*

† If agglomerating, classify in low-volatile group of bituminous class.

‡ Moist B.Th.U. refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.

§ Coals having 69 per cent. or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of B.Th.U.

** It is recognized that there may be non-caking varieties in each group of the bituminous class.

¶ There are three varieties of coal in the high-volatile C bituminous coal group, namely, variety 1, agglomerating and non-weathering ; variety 2, agglomerating and weathering ; variety 3, non-agglomerating and non-weathering.

TABLE III. A CLASSIFICATION OF NEW ZEALAND COALS

Class.	Group.	Locality.	Classification data.	
Bituminous	1. Low-volatile bituminous coal	Paparoa No. 1 seam	Dry F.C. 82.15 per cent. (dry V.M. 17.85 per cent.)	
	2. Medium-volatile bituminous coal	Paparoa No. 2 seam	Dry F.C. 75.14 per cent. (dry V.M. 24.86 per cent.)	
	3. High-volatile A bituminous coal	Liverpool	15,330 B.Th.U.	Dry F.C. is less than 69 per cent. (dry V.M. is more than 31 per cent.)
		Wallsend	15,130 B.Th.U.	
		Dobson	15,000 B.Th.U.	
		Millerton	14,830 B.Th.U.	
		Denniston	14,760 B.Th.U.	
		Murchison	14,360 B.Th.U.	
	4. High-volatile B bituminous coal	Blackball	13,990 B.Th.U.	
		Stockton	13,980 B.Th.U.	
		Blackburn	13,730 B.Th.U.	
		Strongman	13,270 B.Th.U.	
	5. High-volatile C bituminous coal	Hikurangi	12,970 B.Th.U.	Agglomerating
		Reefton No. 2 seam	12,470 B.Th.U.	
Sub-bituminous	1. Sub-bituminous A coal	Wilton	11,500 B.Th.U.	Non-agglomerating and weathering.
		Reefton No. 4 seam	11,390 B.Th.U.	
		Tatu	11,220 B.Th.U.	
		Linton	11,090 B.Th.U.	
		Glen Afton	11,070 B.Th.U.	
	2. Sub-bituminous B coal	Wairaki	10,690 B.Th.U.	
		Pukemiro	10,680 B.Th.U.	
		Rotowaro (Taupiri)	10,590 B.Th.U.	
		Kaitangata	10,460 B.Th.U.	
		Mangapehi	10,230 B.Th.U.	
		Charleston	9,750 B.Th.U.	
		Klondyke	9,680 B.Th.U.	
	3. Sub-bituminous C coal	Mt. Somers	9,420 B.Th.U.	
		Bannockburn	8,440 B.Th.U.	
Lignitic	1. Lignite	Omokoroa (Tauranga)	8,160 B.Th.U.	
		Mataura	7,850 B.Th.U.	

The term "agglomerating," as employed in the A.S.T.M. classification means "weakly coking" and by "weathering" is meant "the tendency of a coal to crumble when exposed to the alternate drying and wetting action of the weather."

ACKNOWLEDGMENT

The writer is indebted to Mr. W. G. Hughson of the Coal Survey Division, Dominion Laboratory, Wellington, for his assistance with several problems that arose during the preparation of this paper.

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A NOTE ON THE LIFE-CYCLE OF *ANOBIUM PUNCTATUM* DE GEER

By J. M. KELSEY, Department of Scientific and Industrial Research, Nelson

(*Received for publication, 17th March, 1948*)

Summary

The life cycle of *Anobium punctatum* De Geer occupies not less than three years in air-dried, sap-wood kahikatea, and not less than four years in air-dired, sap-wood *Pinus radiata* when recently milled. In both timbers the life-cycle for some individuals extended to at least one year beyond the above figures Kiln-dried timber prolongs the life-cycle but does not prevent infestation.

INTRODUCTION

THE results published in this paper are derived from a large series of sap-wood blocks of the following species of timber subjected to oviposition by *Anobium punctatum* from 1943 onwards:—

Rimu—*Dacrydium cupressinum* Soland.
Kahikatea—*Podocarpus dacrydioides* A. Rich.
Totara—*Podocarpus totara* D. Don.
Insignis pine—*Pinus radiata* D. Don.
Tawa—*Beilschmiedia tawa* Benth. and Hook.

The experiments were set up primarily to determine whether or not there was any correlation between length of timber-seasoning period on the one hand, and susceptibility to attack by *A. punctatum* on the other. It was not easy to find the exact dates on which trees were felled and the logs milled, but the dates given here can be taken as accurate to within six weeks.

TECHNIQUE

Timbers used in these experiments were selected from several Auckland mills the owners of which supplied information on milling dates, etc. Boards free from heart were selected, and any of which the identity was too much in doubt was discarded.

Identification of timber species was made primarily by timber merchants and checked by officers of the Department of Scientific and Industrial Research, but though the writer is reasonably certain as to the identity of the species, there is still an element of uncertainty. This is

particularly so in the case of the *P. radiata* as there are several species of conifer being milled under the name of *P. radiata*. In case any question as to timber species arises some blocks have been retained for reference.

Single boards were used for each species of timber, and these were cut into 3 in. × 1 in. × 1 in. blocks and kept under cover for seasoning. Blocks for the first year's tests were left rough, but those for succeeding *Anobium* flight seasons were dressed all round and subjected to the muslin bandage technique (1). Sufficient timber was obtained for carrying on tests over a period of 10 years. Each year 21 blocks for each species were used for the oviposition tests.

Before placing in cages, each block was carefully examined by means of a binocular microscope to ensure that no *Anobium* eggs had already been laid on the surface. This was not easy with rough sawn timber, and was the reason for adoption of the bandage technique described in a previous paper. However, in the first experiments, the time at which the timber was milled would guarantee that no *Anobium* could have oviposited on samples prior to setting up of the experiment. With the bandage treatment of dressed blocks it is extremely easy to see whether eggs have been laid or not, or if larvae have already tunnelled into the wood. The importance of this preliminary inspection is illustrated by the fact that after the third year of seasoning, seven blocks had to be discarded because eggs had been laid during storage of timber.

Three blocks were used in each cage; these were of the Prell type (2) and five female and five male beetles were placed in each.

The *P. radiata* was milled about the beginning of August, 1943, and the kahikatea in March, 1943. The *P. radiata* was subjected to egg-laying from 10/12/43-31/12/43 and the kahikatea from 30/11/44-5/12/44.

Further particulars as to the blocks from which adults emerged are set out in the following table.

Cage No.	Block.	Timber species.	Date eggs laid.	No. of adults emerging.	Date.	Life cycle in years.
48	a.	*P. radiata*	10/12/43-31/12/43	2	—/12/47	4
	c.	,,	,,	4	,,	,,
	d.	,,	,,	1	,,	,,
1	a.	kahikatea	30/11/44-5/12/44	15	,,	3
	b.	,,	,,	3	,,	,,
	c.	,,	,,	2	,,	,,
2	a.	,,	,,	22	,,	,,
	b.	,,	,,	10	,,	,,
	c.	,,	,,	16	,,	,,
3	b.	,,	,,	4	,,	,,
	c.	,,	,,	5	,,	,,
4	a.	,,	,,	24	,,	,,
	b.	,,	,,	14	,,	,,
	c.	,,	,,	4	,,	,,
19	b.	,,	,,	1	,,	,,
21	b.	,,	,,	6	,,	,,

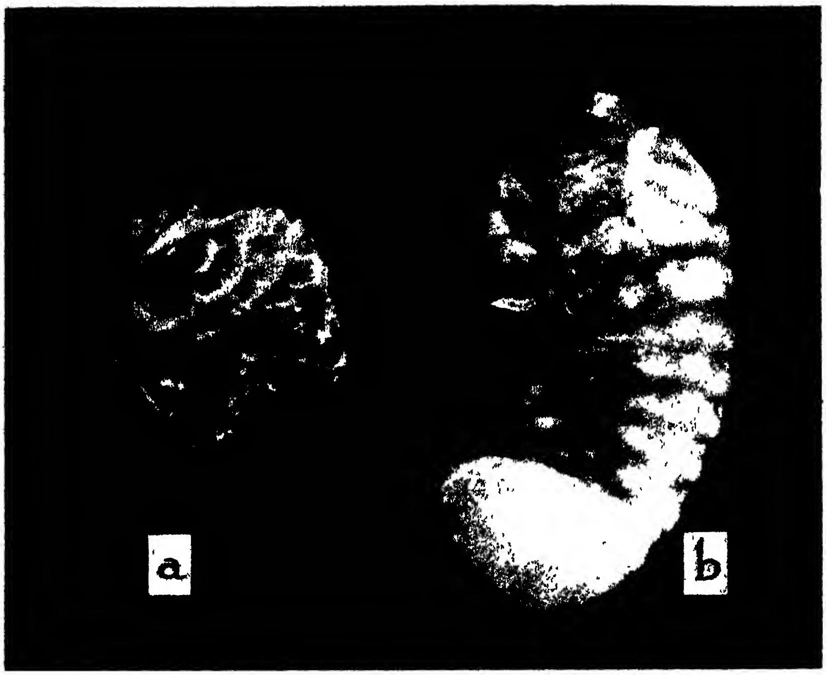

FIG. 1

Kiln-dried timber milled during the same month as the air-dried material and on which *Anobium* laid eggs at the same time, contained live larvae, but these were much smaller than those in the air-dried wood of the same species and age. This is indicated clearly in Fig. 1 which shows :—

(a) a four-year-old larva from kiln-dried compared with (b) a larva of the same age from air-dried *P. radiata.*

Four-year-old larvae were still tunnelling in air-dried and kiln-dried tawa sapwood and were of approximately the same size as those of similar age in kiln-dried *P. radiata.*

To date no live larvae have been recovered from four-year-old air- or kiln-dried rimu or air-dried totara, though larvae had tunnelled in all of these for distances of 3/8 in., and in the air-dried rimu for over 1 3/8 in. before dying.

From these results it can be seen that *Anobium punctatum* has a minimum life-cycle of three years in air-dried, sapwood kahikatea that has been milled for less than one year at time of oviposition, but that some of these larvae may take four or more years to reach maturity.

The life-cycle in air-dried, sapwood *P. radiata* occupies a minimum of four years when timber has been milled for less than one year at time of egg-laying ; here, again, some larvae take at least one year extra to complete the cycle.

Anobium larvae are able to survive for at least four years in both air- and kiln-dried, sap-wood tawa of less than one year in age from milling.

Anobium did not survive ,in either air- or kiln-dried sap-wood rimu that was milled less than one year at time of oviposition, though tunnels varied in length from 1/16 in. to 1 3/8 in. in the air-dried blocks.

Larvae tunnelled for a distance of up to ⅝ in. in sap-wood of air-dried totara, but did not survive.

ACKNOWLEDGMENTS

The writer is indebted to Messrs Henderson and Pollard, Mt. Eden, and the Manukau Timber Co., Newmarket, for supplying the timber for these trials, and to Mr. R. J. Blick of Cawthron Institute, for the photograph.

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LARGE SCALE PRODUCTION OF FISH LIVER OILS

II. FIVE YEARS OF PRODUCTION

By M. M. CUNNINGHAM, C. SCOTT and E. CONE, Karitane Products Society, Wellington

(*Received for publication, 7th July, 1948*)

Summary

An account is given of five years' production of fish liver oils by the Karitane Products Society. During this period a total of 82,329 gallons of oil, or 78 per cent. of the total recorded Dominion production, was attained. Details of plant and processing, and difficulties encountered in collecting raw material are described. Spectrophotometric determination of vitamin A in fish liver oils is discussed, and values obtained for ling, groper and shark liver oils recorded.

INTRODUCTION

DURING 1942 a factory for the production of oils from the livers of New Zealand fish was constructed at Island Bay for the Karitane Products Society. Previous to this, in 1940 and 1941, concern for cod liver oil supplies threatened by war had induced the Society to establish and operate, at their premises in Melrose, a pilot plant. In this plant some 10,000 lb. of fish livers were processed during an investigation designed to show whether large scale production of fish liver oil was in fact a practicable undertaking in New Zealand. During this period techniques of extraction were worked out and details of plant considered; and preliminary trials having proved successful it was decided to undertake commercial production. Delays in building and hold-ups in assembly of plant due to war conditions retarded the official opening of the Island Bay factory until March, 1943, but by that date full factory production had been attained. Details of plant and processing techniques, together with experience gained during the first year of production were summarized by the authors in an article in this *Journal* (1), in which characteristics of the oils produced were also discussed.

In the four years which have elapsed since the appearance of the above-mentioned article production has been carried on at the Island Bay factory in steadily increasing volume; thus the figure of 5,466 gallons of oil produced during 1943-44 had risen by 1946-47 to 23,496 gallons (see Fig. 1). The Society's objective in undertaking the extraction of fish liver oils—namely the provision of a material capable of

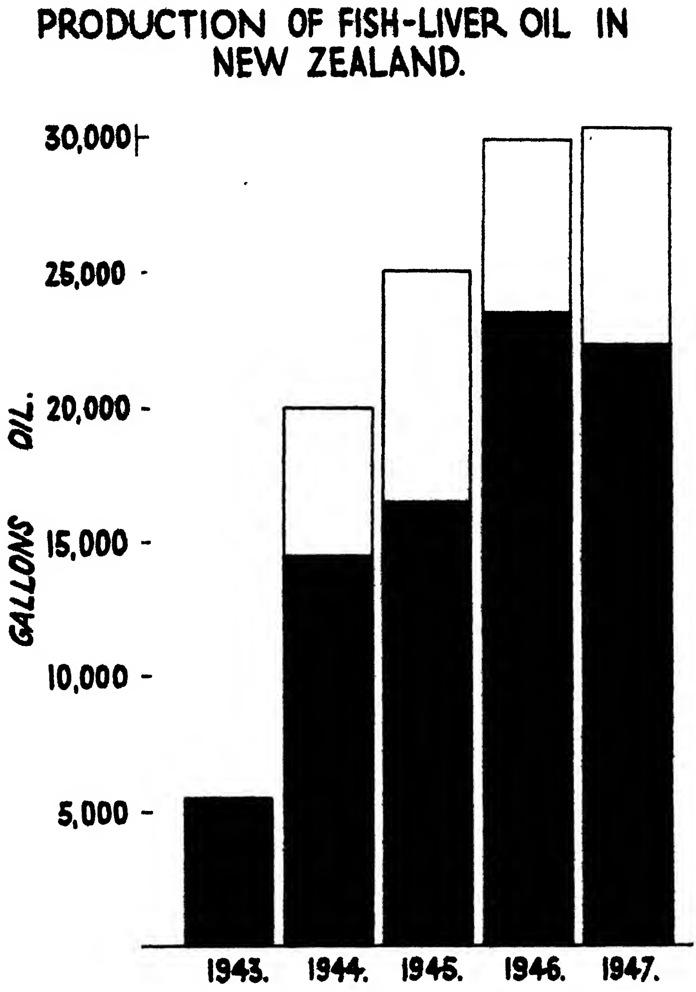

FIG. 1.—Total production of fish liver oils in New Zealand, 1943-48, with production of the Karitane Products Society in black. No figure is available for total Dominion production in 1943.

replacing cod liver oil in the nutrition of the children of New Zealand—was early realized; and it has further been possible to export large quantities of fish liver oils to Britain, and to assist in the rehabilitation of European nations. By the beginning of the current year, however, the fish liver oil industry having been firmly established in New Zealand, and a supply of the essential vitamins A and D assured, the directors of the Karitane Products Society considered that commercial implications consequent on the large production attained were threatening to swamp the real interests of a non-commercial concern, and for this reason have handed over production at Island Bay to another firm. Nevertheless, since for five years three quarters of the total amount of fish liver oil produced in the Dominion has derived from the factory at Island Bay, it is thought of interest to record development of the enterprise in the hands of its initiators.

PLANT AND PROCESSING

One year's operation was sufficient to demonstrate that both plant and accommodation at the Island Bay factory were inadequate to deal with possible supplies of raw material. Early in the second year of operation, therefore, extensive alterations were carried out, the factory being trebled in size, and plant of greatly increased capacity installed.

The "production line" in the original factory was as follows: Taken from cold store, or directly on arrival, livers were cleaned, sorted and fed into power mincers, which in turn discharged the resulting

FIG. 2.—Livers being fed into disintegrators.

sludge to steel digestion pans. Two types of processing were employed, (a) simple treatment with live steam, which is sufficient to extract the oil from livers of high oil content, such as ling and shark, and (b) enzyme digestion, which is necessary for freeing the oil from types such as groper and barracouta. The processed liver slurry was pumped up to overhead tanks whence it was admitted by gravity feed to a Sharples super-centrifuge.

In the new assembly the original refrigerated room was replaced by a completely separate freezing unit capable of storing 10,000 lb. of liver at a temperature of 12°-16°F. Arrangements for cleaning and sorting livers were extended, and the "line" then passed to two five H.P. disintegrators, in which beaters rotating at 3,000 r.p.m. reduced the

livers to pulp and passed them under pressure through sieves and thence to the digestion pans. These disintegrators were found to be much more efficient than the power mincers previously used ; further, since the sieves kept back fragments of connective tissue, etc., from the slurry, the final centrifuging of the processed material was facilitated. Fig. 2 shows livers being fed into the disintegrators, which in turn discharge into the processing pans (see also right hand side of Fig. 3). A third 100 gallon stainless steel digestion pan was added to the existing two.

The most indispensable unit in the efficient production of fish liver oil is undoubtedly the supercentrifuge which separates the oil from water and tissue debris. The Sharples supercentrifuge installed in the first assembly proved itself so satisfactory in operation that in the new

FIG 3.— Disintegrators at top right, discharging slurry into processing pans. Sharples supercentrifuges at left.

layout it was reinforced by two more. With this battery of three centrifuges (see left of Fig. 3), and an increase in the number of overhead feed tanks also to three, it was now possible to process livers simultaneously in three independent operation systems.

Finally, since the oil storage arrangements in the first factory were found to be totally inadequate even for the volume of oil produced during the first year of operation, in the extended plant four 1,250 gallon tanks and one 750 gallon tank were installed and connections established so that oil could be pumped into them direct from the centrifuges (see Fig. 4). A system of pumping was also devised for the circulation of oil within these tanks, in order to ensure uniform characteristics for each tankful of oil. A further improvement on the original plant was the installation of a 250 gallon " blender ". This consisted of a stainless steel cylinder fitted with a horizontal shaft carrying stirring blades and revolving at a low speed, and was used to blend batches of oil to any desired vitamin potency.

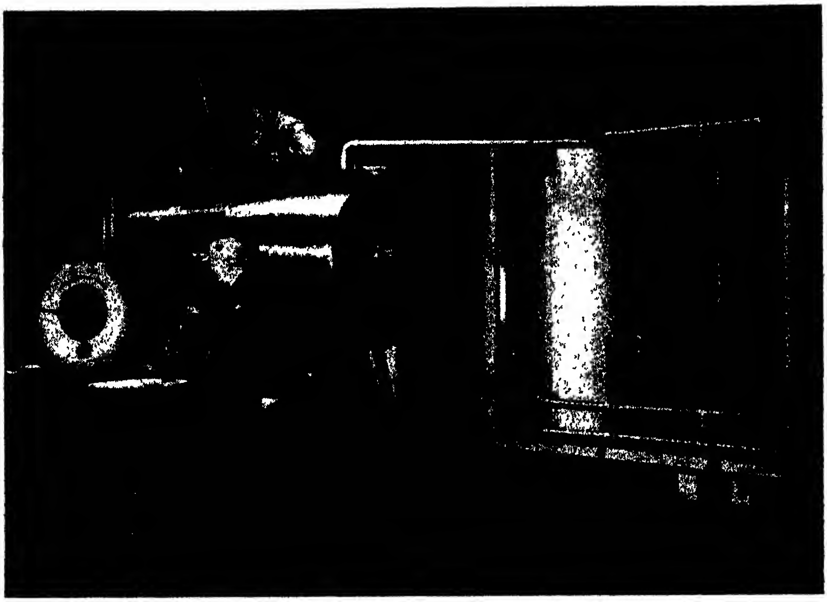

FIG. 4.--Blender and storage tanks.

The extended factory was capable of handling with ease two tons of livers per 8 hour day. As in the first assembly, the plant was largely automatic, and the whole could be run by four men. With these increased facilities production of fish liver oil mounted to 14,500 and 16,500 gallons in the second and third years of production of the factory.

Methods of processing have not been substantially altered during the period under review. In the case of livers from the various sharks, ling and other fish having livers of high oil content, treatment with live steam remains the most suitable method ; by using this method yields up to 70 per cent. of liver weight have been realised with shark livers. It is found desirable to process the livers for a short time only (fifteen minutes is usually sufficient), and to keep the temperature of the slurry as low as possible (not more than 180°F.). When longer processing times or higher temperatures obtain, the presence of oxidised vitamin A is detectable in the resulting oil. This point will be referred to again in the section on measurement of vitamin A. Further, it cannot be too strongly emphasised that for production of liver oils of the highest quality, the freshness of the livers themselves is the most important factor involved. No method of pre-treatment is known which will yield high quality oils from stale livers ; on the other hand, given fresh livers, simple steam extraction followed by centrifuging will invariably yield bland palatable oils, light in colour and low in free fatty acid.

The treatment of groper liver outlined in our previous report has been slightly modified to give improved oil yields and quicker digestion. The rationale of the treatment, however, remains the same, i.e., enzyme digestion of the liver at optimum conditions of pH and temperature. Experience has shown that in the case of slurry from groper livers the first run through the centrifuge sometimes results in incomplete separation of the oil, and it has been found worth while to collect the " stick water " and recentrifuge.

Destearinating.

For medicinal purposes fish liver oils are frequently required to remain clear or free from solid fat at winter temperatures. Thus New Zealand Standard Specification E.216 stipulates that Oleum Genypteri (Ling Liver Oil) and Oleum Galeorhini (Shark Liver Oil) shall be freed from solid fat by filtration at temperatures not exceeding 50°F. and 35.6°F. respectively. This requirement seems to have nothing to recommend it on physiological grounds but is intended to improve the appearance of the oil.

The most complete account of the theory and practice of removal of stearine from fish oils is given by Brocklesby (2), though even here the problem is not cleared up. The main conclusions are (a) that the precipitation of stearine as an oil is cooled is a very slow process, continuing for several weeks after the oil has reached its lowest temperature : (b) that stirring of the oil during cooling is detrimental, causing the stearine to be precipitated as smaller crystals than are obtained from unstirred oil, which makes the subsequent filtration much slower. Brocklesby obtained the desired large crystals in a number of experiments but was unable to define the necessary conditions for their production ; he observed, however, that an oil which had been previously alkali refined gave better crystals.

Our requirements for destearinated oil are small but in order to destearinate occasional batches of oil up to 100 gallons we have developed a process using the minimum of equipment additional to that already installed. It is recognized that this process requires considerable labour and sometimes fails to yield an entirely satisfactory product. 100 gallons of oil are progressively cooled with slow stirring, in one of the tanks which contains a cooling coil connected to a small refrigerating unit. The temperature is reduced to 30°-35°F. in about three days and is maintained at this level for several days longer. The oil is then centrifuged through a Sharples supercentrifuge which is fitted between bowl and casing with a cooling coil, the coil being connected to the refrigerating unit already mentioned. This process results in the removal of about 15 per cent. of the oil as " stearine ". It is of interest to record that the stearine so separated has a vitamin A content which is usually slightly below that of the oil before treatment, and which disappears rather rapidly when the stearine is exposed to the air at ordinary temperatures.

After centrifuging the oil is cloudy, partly on account of its water content which ranges from 0.15 to 0.5 per cent. It is cleared by warming to 110°F. and centrifuging again. Final polishing with a Seitz type filter has recently been adopted (see Fig. 5).

Raw Materials.

During the factory's first year of operation much attention was perforce paid to the contacting of all possible sources for supply of livers, and to the organization of collection from these sources. During the next year great improvements were made in the methods of collection and a considerable measure of success attained in ensuring their arrival at the factory in a fresh state.

In the beginning livers were simply packed at the collecting depots into wooden boxes, and these, where possible, were frozen before despatch by rail or steamer to the factory. By the time they arrived there, most of the boxes were in a lamentable state, exuding blood and oil at

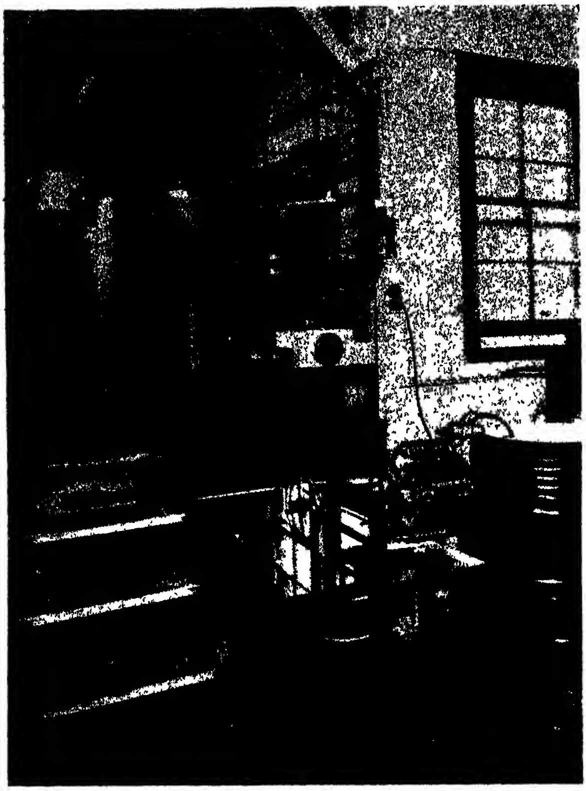

FIG. 5.—The overhead feed tanks for the centrifuges; Seitz type filter press and refrigerating unit for destearinating.

every seam; and the "ripeness" of the livers contained in them was a matter for very adverse comment by the various organisations handling the freight. And of course, as mentioned earlier, the quality of the resulting oils suffered. Approximately seven hundred tinned steel cans each capable of holding 100 lb. of liver, were therefore prepared, and distributed to the various depots. When these cans with their contents were frozen before despatch, the resulting low temperatures inside the cans continued to hold for some considerable time, and consequently the livers were received at the factory in good order. In consequence of this again, the resulting oils were of much better quality, and only occasionally was it necessary to neutralize a batch of oil. Containers insulated with various materials (i.e., cork) were also tried out for conveyance of the livers; but it was found in practice that the small improvement in the condition of the livers was by no means worth the loss of space and increased weight of containers involved.

After institution of the container system, the main difficulty in the way of obtaining fresh livers was delay in inter-island shipping. So serious, in fact, did shipping holdups become, that in 1946 establishment of a subsidiary factory in the South Island was decided upon; and in 1947 a new factory was set up at Timaru to process without any unnecessary delay livers obtained in the South Island. The Timaru factory was equipped, after the style of the parent plant, with digestion pans and centrifuge, and is capable of handling one ton of livers per day.

Laboratory Control.

During the preliminary investigational period and for several years of production, the vitamin A content of oils extracted in the Island Bay factory was determined by the Carr-Price method using a Lovibond tintometer. Conversion to international units was made by a scale of factors varying with the blue values (as reported in the previous article). It was presently apparent that although this method of estimating vitamin A agreed in the majority of cases fairly well with spectrophotometric determinations made by overseas purchasers, yet there were occasional oils (especially some shark liver oils) in which agreement between the two methods was not satisfactory. From the commercial point of view spectrophotometric estimation of the vitamin A content of the oils became increasingly desirable as, to an increasing extent, fish liver oils were bought and sold throughout the world on a price basis calculated on their vitamin A value spectrophotometrically determined. (Since pure vitamin D_2 was obtainable easily and at a low cost, the amount of vitamin D in fish liver oils was generally not taken into consideration by prospective buyers.)

It was therefore decided to adopt spectrophotometric methods for routine determination of vitamin A. Since, however, it was considered that use of an ultraviolet spectrograph with photographic comparison of density would be too inconvenient for routine work, a photoelectric instrument, the Coleman Universal Spectrophotometer, Model 11, was obtained. This instrument, however, proved quite unsuitable for our purpose. In our experience the band width (35mμ) made direct absorption measurements in the ultraviolet unsatisfactory, and attempts to use the instrument to measure the Carr-Price reaction also failed, both because of the band width and also because of the rapid fading of the blue colour under the intensity of light provided. Some workers (3) claim that by reducing the intensity of the exciter lamp to less than 10 per cent. of full brilliance satisfactory measurements can be made of the Carr-Price reaction on the Coleman instrument, but on this point we have no information. Search of the rapidly accumulating literature on absorption spectrophotometry showed that the only available photoelectric instrument combining the essential characteristics of narrow slit, low intensity of illumination and high spectral purity, was the Beckman quartz spectrophotometer (4). This instrument was therefore decided upon.

The Beckman spectrophotometer has proved entirely satisfactory for measurement of the ultraviolet absorption spectra of fish liver oils. By its use optical density at any given wavelength can be conveniently and rapidly determined while reproducibility is of the order of $\pm$ 0.3 per cent. In point of fact it is found that the instrument, without the ultraviolet accessories, is capable of performance beyond the lower limit of wavelength specified by its makers, as measurements can be made with reasonable accuracy at wavelengths down to 300 mμ (20mμ below the specified limit).

For routine purposes it is our custom to determine $E^{1 \text{ per cent.}}_{1 \text{ cm.}}$ on the whole oil at wavelengths of 300, 328, 350 mμ. From $E^{1 \text{ per cent.}}_{1 \text{ cm. } 328 \text{ m}\mu}$ by multiplying by the accepted conversion factor of 1,600 the vitamin A potency of the oil is calculated in International Units per gramme.

To calculate the vitamin A content in "U.S.P. units" it has been customary to multiply the $E^{1\ \text{per cent.}}_{1\ \text{cm.}\ 328\ m\mu}$ value by 2,000, but recently the U.S.P. Committee of Revision has announced the adoption of a new reference standard for vitamin A, and has established a conversion factor of 1,894 (5).

Determination of the absorption spectrum of the whole oil is, naturally, a measure of the vitamin A content of the oil only when there is no appreciable absorption by components of the oil other than vitamin A. It is desirable therefore to consider whether such components are in fact present in appreciable amounts in the sample being examined. It is important first of all to consider oxidised vitamin A. Information as to the presence of oxidised vitamin A is derived from the "extinction ratios" $E^{1\ \text{per cent.}}_{1\ \text{cm.}\ 300\ m\mu} / E^{1\ \text{per cent.}}_{1\ \text{cm.}\ 328\ m\mu}$ and $E^{1\ \text{per cent.}}_{1\ \text{cm.}\ 350\ m\mu} / E^{1\ \text{per cent.}}_{1\ \text{cm.}\ 328\ m\mu}$ especially the former. Below 328 mμ oxidation of vitamin A swings the absorption curve upwards, and the effect is clearly shown if the extinction ratio E 300 mμ/E 328 mμ is compared with that for pure vitamin A. The presence of oxidised vitamin A is less clearly shown on the curve above 328 mμ but the E 350 mμ/E 328 mμ ratio is also taken to show any deviation from the normal. Extinction ratios were first used in this way by Oser *et al.* (6) and the idea was applied by the U.S. War Food Administration in specifying limits for oxidised vitamin A in "acceptable vitamin A containing oil" (7). The limits specified were, for E 300 mμ/E 328 mμ not more than 0.73 and for E 350 mμ/E 328 mμ not more than 0.65. For crystalline vitamin A acetate Morton's figure is, for each of these ratios, 0.57. In our own experience oils carefully prepared from fresh livers have E 300 mμ/E 328 mμ ratios varying from 0.62-0.70, shark liver oils tending to give higher figures than ling or groper. By determination therefore of the three extinctions at 300, 328 and 350 mμ, we are able to estimate the amount of vitamin A in a sample of liver oil, and in addition to judge the extent of oxidation of the vitamin A present in the sample.

More precise estimation of the total irrelevant absorption can be made using the correction procedure of Morton and Stubbs (8). These authors postulate that in the ultraviolet absorption curve of fish liver oil, absorption due to substances other than vitamin A may be assumed to be linear over short intervals of the spectrum. Further, since the absorption curve of pure vitamin A is known, the ratios of extinctions at any given wavelengths to extinction at the maximum for pure vitamin A are also known. Morton and Stubbs therefore select for extinction measurements on the whole oil two points, one on either side of the maximum, and a short distance apart; correction could be made for irrelevant absorption using any two wavelengths, but in practice the calculation is simplified by using two at which for pure vitamin A extinctions are equal. The wavelengths selected are 313 and 338.5 mμ, the ratios E 313 mμ/E 328 mμ and E 338.5 mμ/E 328 mμ being equal and having a value of 0.858. The correction for irrelevant absorption is then a matter of algebra, and reduces in round figures to: E 328 mμ corrected = 7 E 328 mμ gross − 3 E 313 mμ gross − 4 E 338.5 mμ gross (9). To convert the corrected $E^{1\ \text{per cent.}}_{1\ \text{cm.}\ 328\ m\mu}$ value to international units per g, Morton suggests the factor 1,760.

An example will illustrate the application of Morton's correction for irrelevant absorption.

$E^{1\ \text{per cent.}}_{1\ \text{cm.}}$ determined on a sample of shark liver oil was :

at 300 mμ	4.66
at 313 mμ	6.31
at 328 mμ	7.13
at 338.5 mμ	6.18

$E^{1\ \text{per cent.}}_{1\ \text{cm.}\ 328\ \text{m}\mu}$ corrected for irrelevant absorption then becomes :

$$7 \times 7.13 - 3 \times 6.31 - 4 \times 6.18 = 6.26$$

From the uncorrected value of $E^{1\ \text{per cent.}}_{1\ \text{cm.}\ 328\ \text{m}\mu} \times 1{,}600$ the vitamin A potency of the oil is calculated as 11,400 i.u. per g.; while from the corrected figure $\times$ 1,760 the potency of the oil is calculated as 11,000 i.u. per g., 4 per cent. of the apparent potency being due to irrelevant absorption.

This correction is typical for shark liver oils. It will be noted that the E 300/E 328 ratio is 0.65, which in our experience is also usual for shark oils.

Experience enables us to record for various oils vitamin A values outside the range given in our previous communication. Thus values for shark liver oils have ranged from 2,000 to 133,000 i.u. per g., for ling liver oil from 5,000 to 27,000 i.u. per g., and for groper liver oil from 25,000 to 250,000 i.u. per g.

It has not been feasible, with the facilities available, to establish data for seasonal or other variation in liver oils. Some correlation does, however, seem to exist between vitamin A potency and locality. In the case of groper, the average vitamin A potency over a period of one year was 94,000 i.u. per g. for Cook St. livers., and 58,000 i.u. per g. for livers collected on the East Coast of the South Island. As to seasonal potency, it is not possible to say more than that the trend seems to be towards lower potencies in June, July and August, higher values being obtained in March and April. However, high potency oils do occur at all times throughout the year.

For ling liver oil it is only possible to say that in general Cook St. liver oils are again of higher potency than oils from fish caught on the East coast of South Island. The usual figure for South Island ling is 5,000 to 10,000 i.u. per g., while from Cook St. ling batches of oil 18,000 i.u. per g. and over are common. From reports in literature dealing with fish liver oils it would appear that individual variations occurring in members of one species may themselves be very great. To quote from data from Pacific Coast shark fisheries (10): in the species Sphyrna tudes, the hammerhead shark, livers from adult females gave oil of 33,500 to 340,000 U.S.P. units per g., from adult males 58,000 to 87,000 U.S.P. units per g., while oil from livers of sub-adult males varied from 18,875 to 112,000 U.S.P. units per g. With such individual variation it is obvious that possible seasonal changes in vitamin A content can only be followed by statistical examination of large numbers of analyses done on single livers and not on batches of oil produced under factory conditions.

Some vitamin D values have been biologically determined, these as a rule approximating figures previously published by us (1). However, preliminary experiments carried out on groper oils of very high vitamin

A potency (250,000 i.u. per g.) lead us to anticipate that the vitamin D value of these oils is also very high. It is hoped to publish a note on these oils presently. It is of interest to note that oil from the liver of *Polyprion americanus*, a species allied to the New Zealand groper, *Polyprion oxygeneios*, and thought to be identical with the New Zealand bass, is reported from S. Africa (11) as having a vitamin A content of 60,000 to 665,000 i.u. per g., and yet a vitamin D content of only 700 to 1,300 i.u. per g., less than half the vitamin D value of New Zealand groper liver oil.

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THE ECONOMIC STATUS OF *METOPONIA RUBRICEPS* MACQUART

By L. J. DUMBLETON, Entomology Division, Department of Scientific and Industrial Research

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Summary

The literature on this fly, which is considered in Australia to be a minor pest of sugar cane, is reviewed. An attempt to demonstrate its influence on pasture in New Zealand was unsuccessful but larval populations of up to 500 per sq. ft. were recorded in the soil in paspalum-ryegrass-white clover pastures. Severe damage caused by the larvae of this insect has been observed in autumn sown oats. Pre-treatment with soil fumigants and insecticides of plots in an infested field which was later sown in maize, produced differences in growth which correlated well with the reduction in insect numbers in the different plots. Grain yields from the plots showed the same tendency but just failed to reach significance. Early ploughing and working of infested land which is to be sown in maize was shown to reduce the larval population very markedly and is at present the only practicable method of control on maize areas. Observations on other crops confirm that the first crop of maize after breaking up of heavily infested pasture may be a partial or complete failure.

THE occurrence of the Australian Stratiomyid fly *Metoponia rubriceps* Macquart in the Opotiki area was recorded by Muggeridge (5) in 1944. It is now known to occur within an area of about seven miles radius from the township of Opotiki. Large populations of the larvae of the fly

exist in the soil, and these are reported to be the cause of premature deterioration of pastures and of the failure of maize crops, more especially the first crop after grass. A more clear-cut demonstration of the causal relationship of the insect to the damage reported was desirable and the work reported here was directed toward that end and not primarily towards the development of control measures.

REVIEW OF LITERATURE

The Stratiomyid flies as a group are in the majority of cases reported to have saprophagous larvae which feed on materials such as dead plant tissues. In the case of *Metoponia rubriceps* however, Irwin-Smith (3) had reported that the larvae feed on living tissues. The related species *Metoponia prisca* is stated by Evans (2) to be common under raspberry plants in Tasmania but is said to do no damage.

Metoponia rubriceps was first recorded as a pest by Jarvis (4) in 1925 following complaints that it was causing damage to sugar cane near Mackay in Queensland. Large numbers of larvae were reported to be adhering to the roots of stools that had failed to ratoon. The adult insects were flying at the end of May. In the following year Mungomery (6) reported adults flying and pupae present in the soil at the end of June. He records damage to sugar cane roots and mentions that larvae were found on the roots of blady grass, paspalum and couch grass. In one case of damage to cane it was found that the damaged area coincided with that which had previously been occupied by a patch of blady-grass.

Bell (1) in 1934 reported *M. rubriceps* to be more abundant than it had been for eight years. This was thought to be due to wet weather in winter and spring. He recommended ploughing when the insect was in the pre-pupal and pupal stages and the maintenance of a dry surface mulch after the adults had emerged. A communication received from the Director, Bureau of Sugar Experiment Stations, Queensland Department of Agriculture, states that the insect is regarded as a minor pest of sugar cane and has at infrequent intervals caused serious damage in a few localised areas. It is not known to cause any serious damage to pastures in the Bundaberg and Mackay districts where observations have been made on the pest. The adult flies emerge in May or June and the cane is planted in July and August. The control measures recommended are ploughing the fallow fields in April or May, in order to bury deeply the pupae which are present then, followed by light harrowings after the flies emerge in order to expose the eggs to desiccation.

The Queensland areas mentioned above have the rainfall maximum in summer and a relatively dry winter which would tend to increase the effectiveness of the cultural measures recommended for the control of *M. rubriceps*.

LIFE HISTORY

Irwin-Smith's (3) investigations on this insect at Sydney reveal that there are two flight periods for the adult insect. Adults emerged from 11th October to early December from larvae collected in May and August. Adults also emerged on 4th April from larvae collected in early November. In the field, adults were present from early April to mid-May when they were scarce. The information from Queensland given above indicates that in that State the flight period occurs later (May and June). Egg laying commences within a day or two after

emergence. The opaque white eggs are elongate oval in shape about 0.8 mm. long by 0.2 mm. wide. They are deposited at shallow depths in the soil and hatch in two to three weeks. The first stage larvae are about 1 mm. in length and the fourth or final stage larvae are up to 11.0 mm. long. Pupation occurs inside the larval skin and the pupae are therefore not readily distinguished from fully-fed larvae. The pupae tend to occur just below the soil surface. The pupal stage is said to last at least 18 days. Small larvae are present throughout the year and while there is no definite evidence as to the length of the larval period it seems likely that it must occupy at least six months and probably twelve months. It is not known whether there are two races of the insect, with larval periods of equal length, one emerging in spring and the other in autumn or whether, as seems likely, the main emergence is in autumn and those which emerge in spring are delayed individuals which should have emerged in the previous autumn.

In the Opotiki area the seasonal history appears to be very similar to that given for Sydney. The adults are flying in late March and during April. One case of spring emergence has been observed, the fly emerging in late November.

FIELD INVESTIGATIONS ON *M. Rubriceps* IN NEW ZEALAND

An attempt was made to eliminate the larvae from a heavily infested pasture in order to compare the growth of pasture in infested and uninfested soil. The experimental area was a paspalum pasture 15 years old which had been hayed annually for many years and was badly deteriorated. It consisted of paspalum, white clover, weeds and poor grass and a little ryegrass.

Preliminary sampling of the plot gave a mean larval population per sample of 31.6 ± 5.3. The surface area of the sample was $\frac{1}{16}$ sq. ft. and the mean is based on 10 samples.

The plot was 5 yd. by 4 yd. and was treated on 31st July, 1947, with the following emulsion which was poured on to the soil surface :—

dichloroethylether	250 ml.
emulsifier	25 ml.
water	25 gal.

Ten samples taken from the plot on 10/9/47 gave a mean larval population per sample of 44.3 ± 7.3.

As the treatment evidently had no effect in significantly reducing the larval population the plot was divided into two halves, one being treated with chloropicrin and the other with Shell D.D. on 20th October, 1947. The dosage for both materials was 2 ml. per injection, the injections being made 10 in. apart to a depth of 6 in. These plots were examined on 21st November, 1947, when the pasture was found to have been severely affected by the treatment though there was still a large living population of larvae. It seems likely that the difficulty of sealing the injection holes in compacted sod-bound turf was responsible for the poor penetration and kill by the fumigants.

AS A PEST OF OATS

The failure of autumn sown oats, presumably due to damage by *M. rubriceps*, has been reported to occur in the Opotiki district and some details are presented here of an instance of such damage which is without doubt attributable to *M. rubriceps*.

The pasture, which had been down for 5 years, was sown with good seed but the ryegrass faded out. It was ploughed out of grass in March, 1947, and sowed down in oats in April. The growth of the oats was very poor in at least half of the paddock and according to the owner the distribution of the areas of poor oat growth appeared to be correlated with the composition of the pasture previously on those areas. Exploratory sampling of the soil on 31st July, 1947, revealed a moderately high population of larvae of *M. rubriceps* but not nearly as high as in the pasture mentioned in the previous section.

The following means are each based on five samples and represent the larval population in an area of $\frac{1}{12}$ square foot :—

(a)	In an area of poor oat growth	=	18.2 ± 2.3
(b)	In an area of poor oat growth	=	12.8 ± 3.5
(c)	In an area of tall dense oat growth	=	3.4 ± 1.2
(d)	Samples taken over remaining oat plants in a bare area	=	27.2 ± 4.3

There are significant differences between (a) and (c), and (c) and (d). There was thus a large population of larvae in areas of poor oat growth with a marked concentration of larvae round surviving plants, and a low population of larvae in areas of good oat growth. A further 10 samples taken in area (a) on 20th October, 1947, gave a mean larval population of 18.1 ± 4.9.

AS A PEST OF MAIZE

The field of oats mentioned in the previous section was due to be sown down in maize in the spring and it was arranged, in order to test the possible influence of time of cultivation on the level of insect infestation, that one half of the paddock should be ploughed and worked as early as possible and the other half left until just before sowing the maize. The first half was ploughed on 1st August. The subsequent treatment consisted of rolling, double discing and harrowing on 14th and 15th August, and the same operations on 17th and 18th September, cross discing on 21st October and harrowing on 25th October. The second half was not ploughed until 20th October and the subsequent treatment consisted of rolling discing and cross discing on 21st October and harrowing on 25th October.

On each half of the field an experiment was laid out consisting of three randomised blocks each containing the following treatments :—

(1) Control—no treatment.
(2) D.D.T. (2 per cent p.p.i.) dust 7½ lb. per half chain of row worked in to 3 in. depth over a strip 12 in. wide.
(3) Chloropicrin, 2 ml. per injection at 10 in. intervals over the whole plot.
(4) Shell D.D., 2 ml. per injection at 10 in. intervals over the whole plot.

The experiments were located in a part of the field which was presumed to have a relatively even infestation as far as could be judged by the condition of the oat crop.

The treatments were applied between 19th and 21st October, the maize was sowed on 29th October and germination was complete by 9th November. Each plot was 33 ft. × 9 ft. and contained 3 rows of maize. The experimental area was on easy sloping country with an Easterly aspect and on light pumiceous soil.

RESULTS

On 20th November when the plants were in the 4 or 5 leaf stage and about 6 in. high the maize growth on the "early ploughed" half was visibly better than that on the "late ploughed" half. There was no apparent difference in the growth on the different plots nor was there any difference in the strike and establishment on the two halves of the field. The plants in the centre row of each plot were thinned out to approximately 12 in. spacing between plants.

By 15th December considerable differences were evident between the growth on different plots on the "late ploughed" half while the growth on the "early ploughed" half was much better than that on the "late ploughed" half. The growth of the maize on the different plots was graded or scored, on a 0-10 basis, by Mr. Marryatt at this time and also on 5th January. The treatment means for the growth grading on 5th January were :—

Late Ploughed	Control	2.6
,, ,,	D.D.T.	4.0
,, ,,	Shell D.D.	7.0
,, ,,	Chloropicrin	8.0
Early Ploughed	Control	6.6

In early January the height of plants on the chloropicrin and Shell D.D. plots was 18 in. to 24 in. greater than that on the control plots. The differences in height which were noticeable in January tended to disappear in February. Between 11th and 13th January the plots were sampled for larval population, ten samples being taken from each plot, 5 from each outside row. Each sample consisted of a core 6 in. deep and 1/4 sq. ft. area taken over and around a maize plant. As there were no apparent differences between the growth on different plots in the early ploughed half these plots, with the exception of the controls, were not sampled.

The results of the counts of larval populations are given in Table I.

TABLE I. *M. rubriceps* ON MAIZE—MEAN NUMBER OF LARVAE PER PLANT

	Late Ploughed.				Early Ploughed. Control.
	Control.	D.D.T.	Shell D.D.	Chloropicrin.	
Plot Means	33.3 45.5 33.6	14.3 21.2 14.7	10.4 13.1 16.0	4.9 13.0 9.9	6.0 4.7 3.0
Treatment Means	37.46	16.73	13.16	9.26	4.56

The data were subjected to an analysis of variance after transformation to the square root scale. The difference between the controls in the two experiments is highly significant. Within the "late ploughed" experiment all treatments are significantly better than the control. The chloropicrin treatment was significantly better than the D.D.T. but there are no other significant differences between the treatments.

The maize was plucked in early June and shelled and weighed on 20th July. As the actual seed weights were not from the same number of plants in each plot the weights were corrected to give, in each case,

the seed weight per 100 plants. The variation in numbers of plants per plot was not ascribable to insect damage since there was no evidence of loss of seeds during germination or of plants after germination and in any case the plants had been thinned out after germination. The corrected seed yields are given in Table II.

TABLE II. *M. rubriceps* ON MAIZE —SEED WEIGHTS (LB.) PER 100 PLANTS

	Late Ploughed.				Early Ploughed.
	Control.	D.D.T.	Shell D.D.	Chloropicrin.	Control.
Plot Means	40.0 36.8 34.8	32.9 39.4 41.6	34.1 44.2 48.7	50.0 41.8 42.5	40.8 42.0 40.3
Treatment Means	37.2	38.0	45.3	44.8	41.0

An analysis of variance was performed but the tests disclose that the difference between the control treatments in the two experiments is non-significant. For comparisons of treatments in the " Late Ploughed " experiment the variance was partitioned out and the difference required for significance on the 5 per cent. level is found to be 8.5 lb. There are therefore no significant differences between treatments in the " late ploughed " experiment though the differences between the Shell D.D. and control and between chloropicrin and control approach significance.

DISCUSSION

Effect of M. rubriceps on Maize.

There was on the experimental area no significant population of any injurious soil inhabiting insect other than *M. rubriceps*. Any differences in plant growth and seed yield as a result of the treatments is therefore due to the effect of the treatment on the *M. rubriceps* larvae or possibly to a partial sterilization effect of the treatments on the non insect soil fauna. In the " early ploughed " experiment, in which the larval population was low, the growth differences between treatments were not perceptible. There appeared to be no difference in height growth between the " early ploughed " control plots where the low larval population was ascribable to cultivation, and the " late ploughed ", chloropicrin plots where the low larval population was ascribable to the fumigant. There is then no evidence for the existence of a partial sterilization effect and the growth gradings correlate well with the larval populations in the " late ploughed " experiment. Reduction of the larval population of *M. rubriceps* produced appreciably better growth in the maize plants. The most effective treatments produced increases in seed yield but these failed to reach significance. It is probable however that larger plots and greater replication would have demonstrated significant seed yield reductions due to *M. rubriceps* even on this area where the insect infestation could probably be described as medium. There was, for example, no evidence of gross stunting and actual mortality of plants such as was seen on other areas. A nearby crop which was examined in early January when the maize plants on the experimental area were three to four feet high, showed many blanks and perhaps 50 per cent. of the remaining plants only 6 in. high

and some of them dying. These plants had large numbers of *M. rubriceps* larvae crowded eound the main roots. The stunting of growth ascribable to a medium infestation of *M. rubriceps* became most apparent about the third and fourth weeks after germination. It is during this period that the secondary or adventitious roots are developing from nodes on the stem about 1 in. below ground level and normally the period of maximum growth of the plant coincides with the development of these roots. It seems likely that the damage done by *M. rubriceps* larvae is mainly to these roots or to the nodes which produce them. In a heavy infestation the damage may be so severe that these roots are not produced or cannot function adequately and the plant is arrested in growth if not actually killed.

Effect of Time of Cultivation on M. rubriceps.

The direct evidence on this point is to be found in Table I where a comparison of the larval populations on the control plants in the "early ploughed" and "late ploughed" experiments shows that the reduction in population in the early ploughed experiment is highly significant. The treatment of these two sets of control plots differed only in the time at which they received cultivation and the amount of cultivation received. There is no evidence which would enable one to decide how much of this reduction is due to mechanical injury to the larvae during cultivation, to exposure to desiccation and to the virtual absence of living food plants. It may well be that the last factor is the important one.

Effect of Time of Cultivation on Growth and Yield of Maize.

As early as ten days after germination the growth of the maize plants on the "early ploughed" half of the field was visibly better than that in the "late ploughed" half. There was no obvious difference in the rate of seeding or the germination rate on the two halves and the obviously better condition of the early ploughed half was apparently due to more vigorous growth of the plants. Several factors could enter into this result. One is the significantly reduced larval population of *M. rubriceps*. There is however a possible effect due perhaps to better moisture retentivity, better consolidation and better seed bed conditions in the "early ploughed" half and it is not possible to say what part of the effect is due to the soil factors as opposed to the insect factors. In the experiments the differences in seed yields (Table II) between the controls in the two experiments unfortunately did not reach statistical significance. The owner of the field, in the course of plucking the crop, estimated that the early ploughed half had a 20 per cent. better yield than the "late ploughed" half.

A survey of about 30 maize crops in the area infested with *M. rubriceps* was made by Mr. E. R. Marryatt of the Agriculture Department in January, 1947, with particular reference to the condition of the crop in relation to larval population, previous history of the field and time of cultivation. The results lend general support to the belief that insect damage is very much reduced on land ploughed at least three months before sowing. Variations in soil type, and in the amount and frequency of cultivation subsequent to ploughing, probably make it difficult to obtain a clear cut comparison of the effects of early and late ploughing.

CONTROL MEASURES

The Queensland recommendations are for ploughing when the prepupae and pupae are present. Under New Zealand conditions this

would be during March. It is a common practice in the Opotiki area to plough out the pasture in March and to sow green feed oats in April. Several cases have been observed where such oat crops have failed owing to damage by *M. rubriceps* and it is apparent that the normal routine of cultivation while it may reduce the larval population, may not reduce it sufficiently to prevent serious damage. It is not known what percentage of the larvae attacking the oat crop consists of survivors from those existing in the pasture previously and what percentage, if any, is due to egg laying by the flies after the field is broken out of pasture and cultivated. It is known that old pastures may have a larval population of up to 500 larvae per sq. ft. In the field in which the experiments were located, the larval population after sowing the oats was still of the order of 200 per sq. ft. and this was high enough to visibly affect the growth of the maize. The initial population when this field was in pasture is not known.

As to the recommendation for frequent harrowing and the maintenance of a dry surface mulch during the egg laying period, this would require to be done in April and might make it impossible to sow the oat crop early enough to ensure a satisfactory yield. The Australian recommendations are for an area which has its lowest rainfall during the winter months, whereas the Opotiki area has its rainfall maxima in autumn and spring. It seems doubtful whether the mechanical and desiccating effect of cultivation over a short period in autumn would have much effect on the larvae. Where the pasture is heavily infested and it is known that an oat crop is liable to be a failure it may be advisable, when it is intended to sow maize in the spring, to plough out of grass in March as usual but to leave the area as a bare fallow over winter employing frequent cultivation to eliminate weed growth. An oat crop sown after grass should be ploughed in as early as possible, preferably by the beginning of August and the area kept free from volunteer growth and weeds until it is sown. The frequent working which is necessary will probably be more practicable on the light soils of the undulating hill country than on the heavier soil of the flats.

CONCLUSIONS

(1) Evidence is presented to show that severe stunting of oats and maize can be caused by the large populations of *M. rubriceps* larvae which may be expected to be present when old pasture is broken out of grass at Opotiki.

(2) The use of the soil insecticides or soil fumigants which were used to reduce the larval population on the experimental plots would not be practicable as a control measure on maize crops because of their high cost.

(3) The larval infestation was significantly reduced and the growth of maize was improved by ploughing and working the field three months before sowing the maize.

ACKNOWLEDGMENTS

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Agriculture, advised on details of the layout of the experiment and provided the Shell D.D. The counts of larval populations were made by Mr. J. Timlin. Finally I am much indebted to Mr. H. R. Thompson, Biometrics Section, Department of Scientific and Industrial Research, for statistical analysis of the experimental work.

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BEHAVIOUR OF SULPHUR DIOXIDE IN DEHYDRATED VEGETABLES

By J. L. MANGAN and B. W. DOAK, Plant Chemistry Laboratory, Department of Scientific and Industrial Research, Palmerston North

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Summary

(1) The Monier-Williams method for determining the sulphur dioxide content of dehydrated foods is not specific, and there is evidence that the iodometric method using formaldehyde gives more correct values.

(2) Warm storage experiments showed that sulphur dioxide is lost from dehydrated vegetables by two processes (a) by direct oxidation to sulphate and (b) by an unidentified reaction which does not require the presence of oxygen, and which accounts for the greater part of the loss of sulphur dioxide.

(3) This second process is not an auto-oxidation involving inorganic intermediates.

INTRODUCTION

IN the determination of sulphur dioxide in dehydrated foods it has been found that in general the Monier-Williams distillation method (1) and the direct iodometric titration method of Reifer and Mangan (2) show good agreement. However, in the case of warm stored samples of dehydrated vegetables considerable discrepancies have been observed,

and in this paper these differences have been investigated not only for the purpose of determining the specificity of each method, but also to elucidate as far as possible the mechanism of the disappearance of sulphur dioxide and the final products of the reaction. The direct titration method makes use of the reaction between sulphur dioxide and formaldehyde forming a stable hydroxy-sulphonic acid which is not oxidised by iodine, and would thus appear to be more specific than the Monier-Williams method which measures the acid formed by distilling the sulphur dioxide, and possibly other volatile compounds, into hydrogen peroxide.

A brief investigation of the Monier-Williams method showed that compounds other than sulphite give appreciable titration figures. Thus tetrathionate, thiosulphate, dithionate and thiourea were found to give " sulphur dioxide " figures varying from a trace in the case of thiourea to large amounts from thiosulphate and dithionate. Dithionate, a common product of the oxidation of sulphite, although very stable in its chemical properties, yielded almost 90 per cent. of the theoretical sulphur dioxide in the usual Monier-Williams procedure, and in later work (3) this was made use of in the accurate determination of small amounts of dithionate. Hydrogen sulphide, cystine and a few other organic sulphur compounds were found to give negative results, although Monier-Williams (1) gave figures which showed that volatile organic compounds such as the mustard oils could produce rather small amounts of sulphuric acid in the hydrogen peroxide. None of the above compounds gave a figure by the direct titration method.

A recent paper (4) on the Monier-Williams method describes improvements involving the use of nitrogen in place of carbon dioxide, and titration of the acid formed in the peroxide using a glass electrode to determine the end point. In the official A.O.A.C. method the end point is not particularly sharp, but experience in this laboratory over several years has shown that the method gives very consistent results. A number of determinations comparing the use of carbon dioxide and nitrogen with bromphenol blue and with a glass electrode/calomel electrode assembly to determine the end point is shown in Table I. For normal accuracy the A.O.A.C. method compares well with the modified method, and in view of its simplicity the A.O.A.C. method was used throughout the present investigation.

TABLE I. MODIFICATIONS OF MONIER-WILLIAMS METHOD

Sample.	CO_2/Bromphenol blue to pH 4.5.	CO_2/Glass electrode to pH 4.5.	N_2/Bromphenol blue to pH 4.5.	N_2/Glass electrode to pH 6.0.
Dehydrated Carrot	644 p.p.m. 648 ,, 689 ,,	684 p.p.m. 648 ,, —	688 p.p.m. 684 ,, 703 ,,	665 p.p.m. 700 ,, —
Dehydrated Cabbage	1,525 ,, 1,490 ,,	1,490 ,, 1,400 ,,	1,537 ,, 1,490 ,,	1,418 ,, 1,490 ,,
Dehydrated Cabbage	22,750 ,, 22,750 ,,	22,750 ,, 22,925 ,,	22,900 ,, 23,100 ,,	22,750 ,, 23,600 ,,

The potentiometric titration curves showed that the buffering effect of the carbon dioxide dissolved in the peroxide is apparent only above pH 5, and thus does not affect the bromphenol blue end point. Although compounds other than sulphite are measured in the Monier-Williams method, it has not been recorded in the literature that the method is untrustworthy in the case of dehydrated vegetables.

WARM STORAGE OF DEHYDRATED CABBAGE

In the warm storage of dehydrated cabbage containing over 1000 p.p.m. of sulphur dioxide, differences were observed (2) in figures obtained by the Monier-Williams and the direct titration method. In samples containing up to 2000 p.p.m., however, the differences were too small for detailed investigation; a batch of cabbage was, therefore,

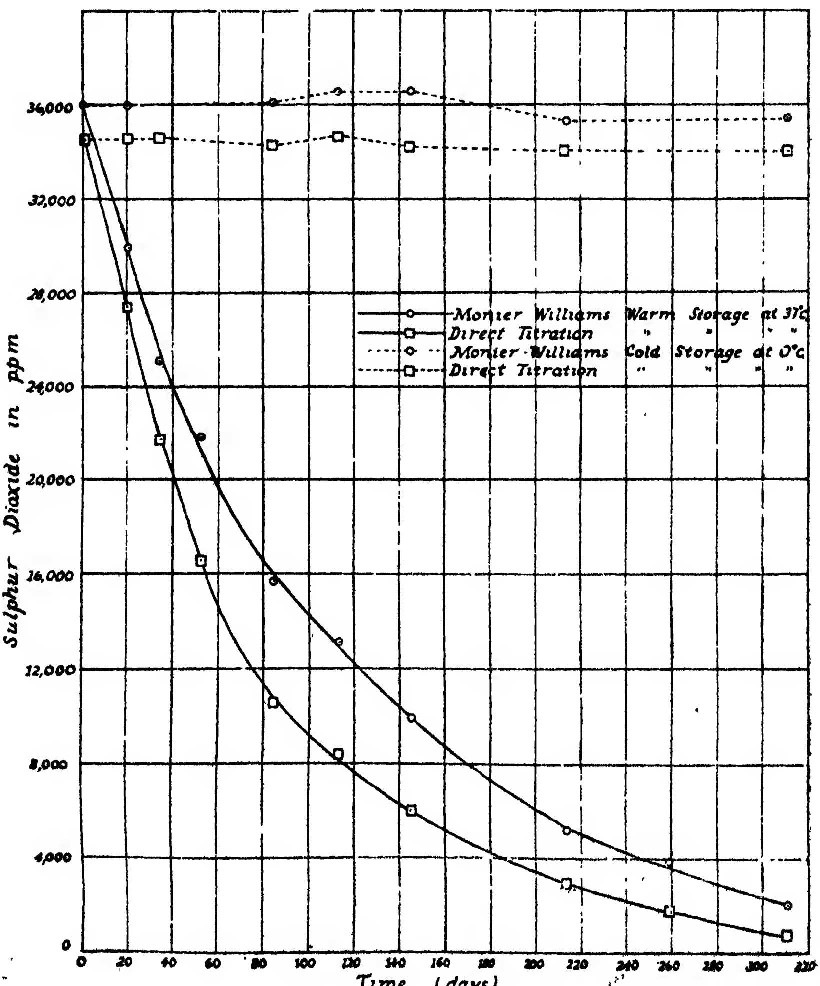

FIG. 1

dehydrated after heavy sulphite treatment, yielding a product with 36,000 p.p.m. of sulphur dioxide. The whole sample was ground in a laboratory mill and the sulphur dioxide determined by the two methods. A control sample was then placed in the refrigerator and the remainder in a warm storage incubator at 37°c. The sample was kept in a sealed glass vessel containing abundant air. Sulphur dioxide was determined periodically on the samples and the results are plotted in Fig. 1.

It is seen that the sulphur dioxide content of the control sample, except for experimental errors, remained fairly constant throughout storage, and that the original small difference between the two methods remained almost unchanged. In the warm storage sample the sulphur dioxide content fell rapidly and at the same time the difference between the two methods increased, until at the end of 100 days the difference amounted to 36 per cent. of the Monier-Williams figure. The sulphur

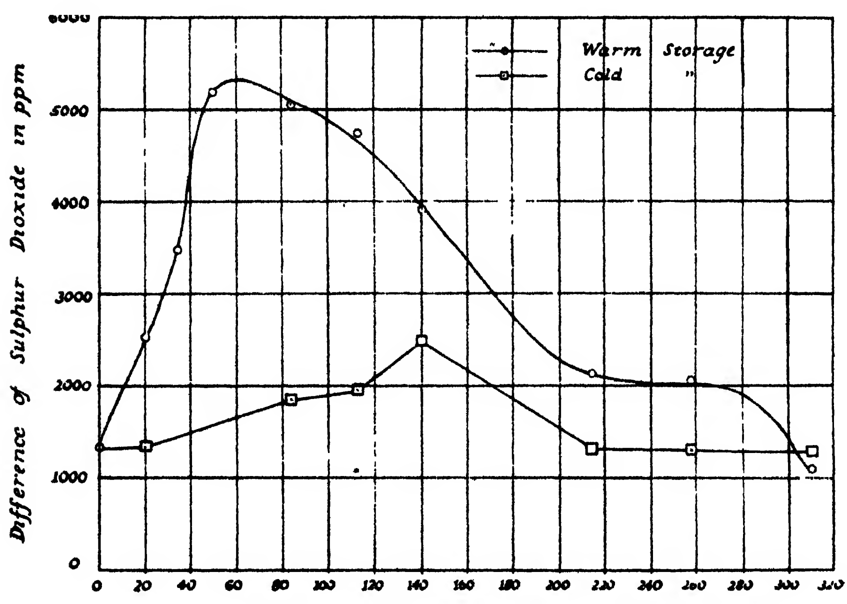

FIG. 2

dioxide content continued to fall, but the "difference SO_2" after reaching its maximum, rapidly decreased to approximately the original difference figure. The sulphur dioxide content by this time had fallen to a low figure, the curves had flattened out, and were gradually approaching zero. Fig. 2 shows the plot of "difference SO_2" against time. It would appear from these results that a reaction is proceeding in which sulphur dioxide is forming a compound which can be determined by the Monier-Williams but not by the direct titration method, and that the concentration of this compound rises to a maximum and then decreases to zero. It is of interest to note that the sample showed its first discolouration approximately at the peak of this curve, and gradually became brown despite the presence of about 10,000 p.p.m. of sulphur dioxide.

WARM STORAGE IN DIFFERENT ATMOSPHERES

Heavily sulphited cabbage was prepared as for the previous experiment and stored under the following conditions:—

(a) In high vacuum at 37°c.
(b) In carbon dioxide at 37°c.
(c) In air at 37°c.
(d) In oxygen at 37°c.

With samples (a) and (b) care was taken to remove all oxygen. A control sample was placed in the refrigerator and storage carried out as before. Figs. 3 and 4 show the results.

The sample was unfortunately very dry and the loss of sulphur dioxide correspondingly slow. After about 250 days, by which time sufficient information had been obtained, the storage was discontinued.

The most important result was that samples stored in oxygen-free atmospheres, whether in carbon dioxide or in vacuum, lost sulphur dioxide almost as rapidly as those stored in pure oxygen. The differences between vacuum and carbon dioxide storage, and between air and pure oxygen, were not significant. In all four storage experiments the difference between Monier-Williams and direct titration figures increased as in the original experiments. It is thus apparent from these results that there are two processes by which sulphur dioxide is lost, one which

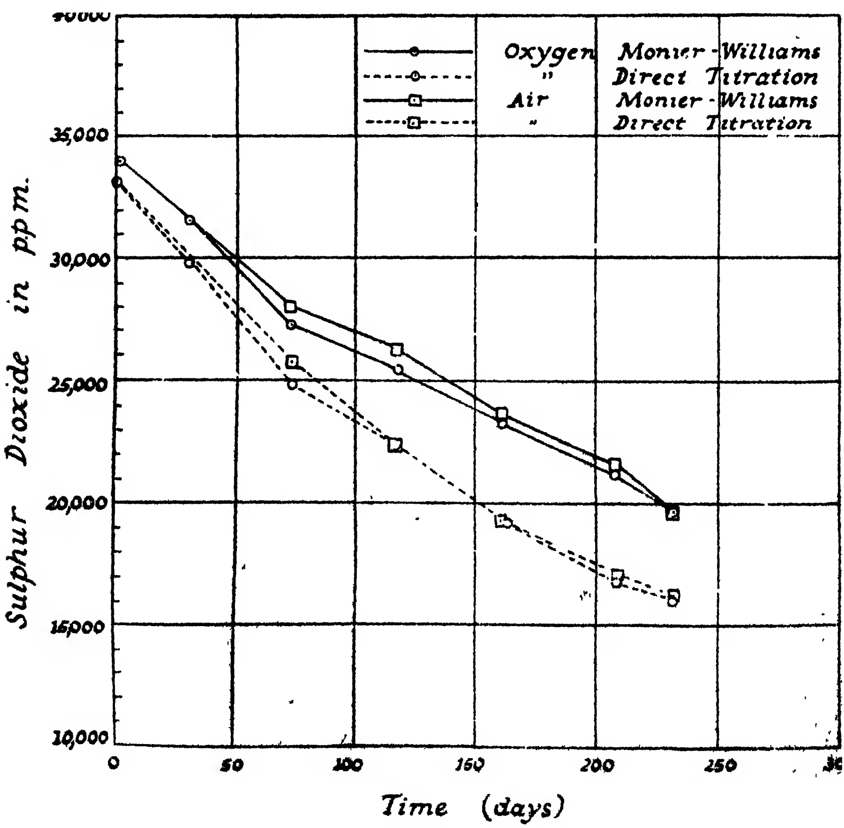

FIG. 3

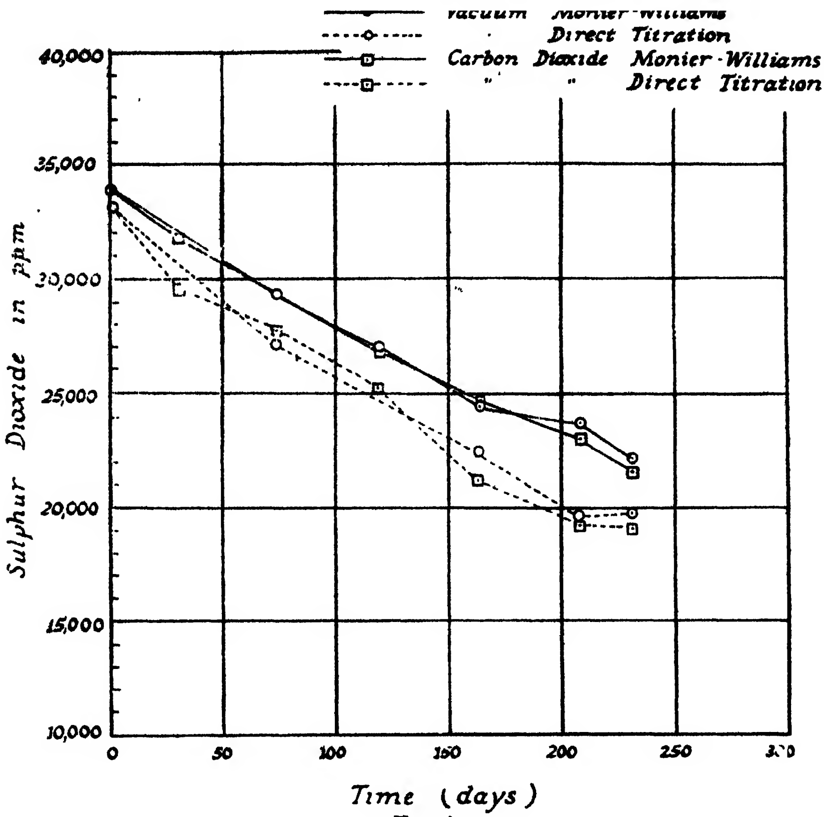

FIG. 4

does not require the presence of free oxygen and which accounts for the greater part of the sulphur dioxide lost, and a second process which is due to the presence of oxygen and which probably involves a straightforward oxidation of sulphite to sulphate.

The "anaerobic" loss of sulphur dioxide proceeds at a rate some five or six times as fast as that due to direct oxidation, and although there is no indication of the nature of this loss, a number of auto-oxidations of sulphite have been recorded in the literature, usually however under more vigorous conditions (5, 6). The presence of dithionates, thiosulphates, etc. as intermediates in such an auto-oxidation would explain the differences observed between the Monier-Williams and direct titration methods as shown in Fig. 2.

To investigate this further a method of analysis was developed in which dithionate, polythionate, sulphate, thiosulphate, sulphite and sulphide could be separated and determined on the one solution and in the presence of plant materials (3). The method depends for separation on the solubilities of the lead salts and will be referred to as the "lead separation" method.

ANALYSIS FOR PRODUCTS OF OXIDATION OF SULPHUR DIOXIDE

Samples of dehydrated cabbage and of carrot, both with high sulphur dioxide contents, were kept in warm storage at 37° C. for 110 and 75 days respectively, with control samples in the refrigerator. On analysis

for sulphur dioxide by both methods, little change had occurred in the control which was then taken as equivalent to the original sample prior to storage. The warm storage sample and the control were then estimated for inorganic sulphur compounds by the lead separation method mentioned above.

1 g. of the dehydrated vegetable was macerated with 100 ml. of boiling water, and after cooling the mixture was titrated to pH 8 with 0.1N.NaOH using a glass electrode. This pH is sufficient to decompose any sugar-bisulphite compounds which may be present. Another 1 g. sample was then dropped into 100 ml. of boiling water containing glycerol to protect the sulphite from oxidation, and the required amount of sodium hydroxide. The flask was then immediately stoppered and placed under a running water tap. The resultant vigorous boiling disintegrated the tissue, and extraction was completed by blending for 1 minute in the Waring Blendor. The extract was made to 300 ml. with alcohol, filtered, and 40 ml. aliquots analysed by the lead method described above (3). Results are expressed in Table II.

TABLE II.

Sample.	Dithionate. g $H_2S_2O_6$/100 g.	Poly-thionate.	Thiosulphate. g.$H_2S_2O_3$/100 g.	Sulphite. g.SO_2/100 g.	Sulphate. g.H_2SO_4/100 g.
Cabbage Original	Nil	Nil	0.39	2.002	1.714
Warm Storage	Nil	Nil	0.57	0.048	2.325
Carrot Original	0.137	Nil	0.013	1.27	0.87
Warm Storage	0.135	Nil	0.014	0.61	1.14

It is seen that apart from sulphite and sulphate, no appreciable change has occurred in the inorganic sulphur compounds, and also that the changes in these two do not correspond. Thus in the case of the cabbage sample the loss of sulphur dioxide corresponds to 0.978 g. sulphur/100 g., while the gain as sulphate is only 0.199 g. sulphur/100 g. sample. Thus only about one-fifth of the sulphur dioxide is oxidised to sulphate, a figure which is in agreement with the results obtained from the storage experiments under aerobic and anaerobic conditions, and supports the proposal that two mechanisms are in operation for the loss of sulphur dioxide in dehydrated vegetables. Of 0.340 g. sulphur lost as sulphur dioxide from 100 g. of the carrot sample, only 0.088 g. appeared as sulphate.

COMPARISON OF MONIER-WILLIAMS, DIRECT TITRATION AND LEAD SEPARATION METHODS FOR SULPHUR DIOXIDE

The lead separation method has also been used as an independent method for the comparison of the other two methods. A number of analyses are given in Table III below, and to overcome any error which might occur in the lead method due to the extraction process, some extracts were also made and the three methods then applied.

TABLE III. COMPARISON OF METHODS

Sample.	Monier-Williams.	Direct Titration.	Lead Separation
Dehydrated Cabbage A	24,700 p.p.m.	21,700 p.p.m.	21,650 p.p.m.
,, ,, B	30,300 ,,	28,300 ,,	27,000 ,,
,, ,, C	23,400 ,,	19,900 ,,	20,200 ,,
,, Carrot A	13,500 ,,	13,450 ,,	12,700 ,,
,, ,, B	7,930 ,,	6,700 ,,	6,020 ,,
Cabbage Extract A	7,700 ,,	7,150 ,,	7,210 ,,
,, ,, B	3,020 ,,	2,500 ,,	2,400 ,,
,, ,, C	3,800 ,,	3,580 ,,	3,460 ,,

It can be seen that the lead separation method agrees well with the direct titration method. The maximum variation from the lead separation method, expressed in percentages of this figure, demonstrate this tendency. The Monier-Williams figures vary from + 31.6 per cent. to + 6.3 per cent. whereas the direct titration figures for the same samples were within the limits + 5.9 per cent. to – 1.5 per cent. It should be noted that all the samples in Table III (except carrot A), were from warm storage, and there were appreciable differences between Monier-Williams and direct titration. A few brief trials showed that sulphite even in the presence of large excesses of ketones, glucose or fructose was completely precipitated in the lead method, provided that the pH was adjusted to 7.5-8 before the addition of lead acetate. Formaldehyde, acetaldehyde and benzaldehyde in large excess completely prevented the precipitation of the sulphite. Thus the lead precipitation method, and hence the direct titration method, measures free sulphite and sulphur dioxide loosely bound as in the sugar-bisulphite compounds, and it is apparent that the Monier-Williams method is measuring sulphur dioxide generated from more stable compounds which probably serve no useful purpose in the preservation of the dehydrated vegetables.

DISCUSSION

The standard Monier-Williams method, although reliable for freshly dehydrated vegetables, can give erroneous results in stored samples. As this error is not overcome by modifications such as using nitrogen as the carrier gas and the glass electrode for titration, it would appear that fundamentally the method is not sufficiently specific.

The storage experiments would indicate that, at least at elevated temperatures, the packing of dehydrated vegetables in carbon dioxide or nitrogen does not prevent the loss of sulphur dioxide. Although the connection between browning and sulphur dioxide content is not known exactly, it is safe to say that the more rapid the loss of sulphur dioxide, the earlier does browning occur. Hence a high moisture content and a warm storage temperature would probably outweigh the relatively small benefit derived from the removal of oxygen.

The cause of the loss of sulphur dioxide from dehydrated vegetables has not been found, but it has been shown that only a small portion of this loss is lue to direct oxidation, and that the remaining loss is not due to a series of inorganic oxidation-reduction reactions. This would imply that the sulphur dioxide is involved in organic reactions, and the most probable explanation would seem to be that hydroxy-sulphonic acids are formed by reaction between sulphite and aldehydic groups,

and that oxidation-reduction reactions then occur forming stable sulphonic acids without the necessity for the presence of free oxygen. Browning, which has been observed when large quantities of sulphur dioxide are still present, might be connected with such an oxidation-reduction reaction.

ACKNOWLEDGMENTS

We wish to thank Dr. I. Reifer for his interest and helpful suggestions.

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POST-GLACIAL CHRONOLOGY AND CLIMATE HISTORY

Pollenanalytische, stratigraphische and Geo-chronologische Untersuchungen aus dem Faulenseemoos bei Speiz, von Max Welten. Veröffentlichungen des Geobotanischen Institutes Rübel in Zürich 21 Heft. Verlag Hans Huber, Bern, 1944.

CLIMATE, land forms, soils, plant cover, animal population—the history of any one of these reflects the influence of the others—climate history is of interest not only to the meteorologist, but also to the geologist, the pedologist and the biologist. Inspired by progress in the elucidation of recent climate history in the northern hemisphere Speight in 1911 published some deductions, based on plants and plant remains, concerning the post-glacial climate of Canterbury. Allan, in 1926, obtained similar results from a study of the vegetation of Peel forest (Canterbury) and these conclusions were supported by the work of Cranwell and von Post on pollens from some Otago bogs—published in Sweden in 1936 and in the New Zealand Journal of Science and Technology in 1938 (Fossil Pollens by Lucy M. Cranwell). By this time it could be fairly confidently assumed that in New Zealand, as in the northern hemisphere, there had been a middle warmer period in the post-glacial climate history. Nothing was known, however, of the rate of growth of our peat bogs and from these, the most likely source of evidence on climate and vegetation development, there seemed little prospect of obtaining a very definite time scale. Moa bones had been found but no artifacts which could be dated by archæologists as in the case of some northern deposits. And even

FIG. 1
Photograph of a section of lake sediments showing annual layering.

where other evidence could be found for the construction of a time scale there must inevitably be less opportunities for correlation and confirmation in the southern hemisphere, where land masses within the zone of pleistocene glaciation are so small and isolated, than in the north where the ice had advanced over continents.

Our main hope of a time scale in New Zealand seems to depend on evidence of world-wide changes which would permit us to apply, at least as a working hypothesis, the chronology worked out in northern countries. A recent book by Zeuner (Dating the Past) gives a comprehensive but very concise discussion of the methods employed for extending a chronology backwards from historical times —tree rings, varve analysis, solar cycles, pollen analysis, radioactivity and the rates of biological evolution and of geological processes. Neither this book, nor the summary by von Post, in the "New Phytologist," of recent work in pollen analysis, makes reference to some important work done in Switzerland during the war years and described by Welten in the publications of the Rübel Institute of Zürich.

This author found a small lake in the Alpine Foreland of Switzerland where, from the time when it was uncovered by the melting ice of the last glaciation, deposits began to accumulate which showed a distinct layering and which, owing to the undisturbed nature of the lake-bottom, were continued and well-preserved up to the time when the lake was artificially drained. During the summer growing season the organic sediments formed a dark-coloured layer which alternated with the lighter-coloured mineral deposits brought in by seasonal flooding. This distinct alternation of sediments exhibited a layering which was found to be of an annual character and, by careful handling of the material, Welten was able to determine and compare the absolute annual sedimentation and pollen deposition. The rate of sedimentation was in itself an index of year to year fluctuations in weather conditions while the pollen rain reflected changes in the surrounding vegetation over longer periods. It has been possible, therefore, not only to calculate the time lapse in years but also to indicate changes in climate and vegetation.

The paper is some 200 pages in length. Of the seven chapters, the first contains the introduction and some remarks on method. There is a good discussion of sources of error, particularly those which might arise from faulty sampling technique, and of the appropriate sampling interval. The next two chapters deal with the pollen diagrams and stratigraphy of the post-glacial and late-glacial respectively. Chapter IV is devoted to the problem of distinguishing the pollens of different species of *Betula* and *Pinus*, and, in connection with these, to the species composition of the late ice-age forest of Lake Faulen. This author's application of statistical method to the study of pollens of these two genera is of particular interest as his ideas may prove equally applicable to the pollens of the beeches and conifers of the south—in all probability to the former at least.

Chapter V (Geochronological investigations) and VI (Sedimentation and bog stratigraphy), are likely to be of interest to geologists for the discussion of layering in the lake sediments and its preservation, the reciprocal fluctuations in the proportions of different sediment types such as lake chalk and gyttja, late- and post-glacial chronology, possible sources of error in computing the number of years represented, and finally, for the mathematical solution to the problem of relating a truncated series to the Christian time-reckoning.

An important section of Chapter VI is that dealing with the absolute annual pollen deposition and the absolute pollen diagram. The presentation of an absolute pollen diagram is a special feature of the work and it is doubtless the first to be published.

The final chapter is in the nature of a résumé, and a translation of this, prepared by the present writer (with the assistance of colleagues), is available for consultation. There are thirty figures in the text, including a photograph showing the annual layering, the pollen and sediment diagrams, a section of the lake deposit showing stratigraphy, and tables showing sequences and time-scales based on time reckoning in years B.C. and A.D. Succession of forest dominants, climate succession and archæological chronology are also covered. As the work is not generally accessible in New Zealand the photograph is here reproduced from a negative kindly lent by the author and a table, compiled by the reviewer, is appended showing some correspondences with von Post's post-glacial climate periods, as applied by him to Northern Europe and to New Zealand and with the modified Blytt-Sernander scheme of current literature.

W. F. HARRIS,
Botany Division, D.S.I.R.

CLIMATE AND FOREST HISTORY IN LATE AND POST GLACIAL TIME

SOME COMPARISONS BETWEEN THE SCHEMES OF WELTEN, VON POST AND OTHERS

(Compiled by the Reviewer)

Time in Years B.C. and A.D.	Welten's Scheme Alpine Foreland of Mid-Europe.		Von Post's Scheme for Northern Europe and New Zealand.		Modified Blytt-Sernander Scheme.		Archaeological.
	Forest type.	Climate.	Forest type.	Climate.	Period.	Climate.	Period.
A.D. 1900							
	Mixed beech						
			Beech	III			
1250		Warm					
	Beech	moist		Decreasing	SUB-	Cool	IRON
850		Cool	(*Nothofagus*		ATLAN-	humid	AGE
	Mixed	moist	and grass-	Warmth	TIC		
	beech		land in				
600			New Zea-				
	Beech	dry	land)				
200							
001	Mixed	Cooler					
B.C.		and					
450	beech	moister					
	Beech		"GRENZHORIZONT"				
750							
	Mixed	Warm			SUB-BOREAL	Drier continental	BRONZE AGE
	beech	dry					
1800							
	Fir	moderate					
2350			Mixed Oak	II			
		Warm					
	Beech			Post		Warm-	
		moist	(Podocarp	glacial	ATLAN-	humid	
			in New		TIC	Climatic	
3200			Zealand)	Warm		Optimum	
				period			STONE
	Mixed						
	oak	Warm					
		Dry					
	Hazel						
5050							
		Cool					
	Pine				BOREAL	Warm-dry	
		rather				continental	AGE
		moist		I			
			Birch-				
6350		Gradual	Pine	Increasing			
	Birch	amelior-	(Grassland				
6630		ation	in New	warmth			
			Zealand)		PRE-	Cool-	
		Cold			BOREAL	humid	
	Willow						
		moist					
7500	(alpine						
	tundra)						
7550		Retreat of glaciers					

LABORATORY BREEDING OF THE HOUSEFLY (*MUSCA DOMESTICA L.*)

By R. A. HARRISON, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(*Received for publication, 1st April, 1948*)

Summary

For breeding houseflies in large numbers throughout the year the Peet-Grady method has been modified in several particulars.

Chief of these are the use of a dual purpose feeding and oviposition tube, and a new method of obtaining pupae from the larval medium.

By burying a petri dish, containing cotton wool half an inch below the medium surface before eggs are added, clean pupae are obtained quickly and without injury

DURING the past two years houseflies (*Musca domestica* L.) have been bred in large numbers for use in testing insecticidal properties of D.D.T. The breeding technique originally followed was the Peet-Grady method published by Schwarcz (1943). Various modifications to the method have been made in this laboratory and these are described in detail.

EQUIPMENT

Breeding Room.

This is an artificially lighted room maintained at a constant temperature of 27.8°c. ± 0.5°c. and a relative humidity of 53 per cent. ± 2 per cent.

Larval Breeding Jars.

For this purpose one gallon "Duraglas" syrup jars, 6 in. in diameter and reduced to 6 in. in height are used.

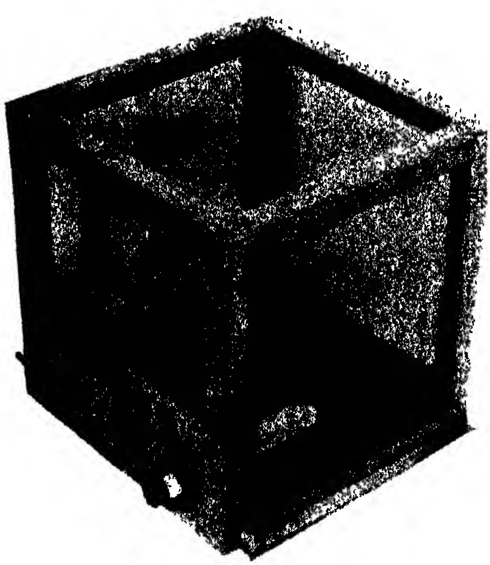


FIG. 1.—Adult fly cage with oviposition tube. Approx. × ⅛. *Photo: R. I. Hughes*

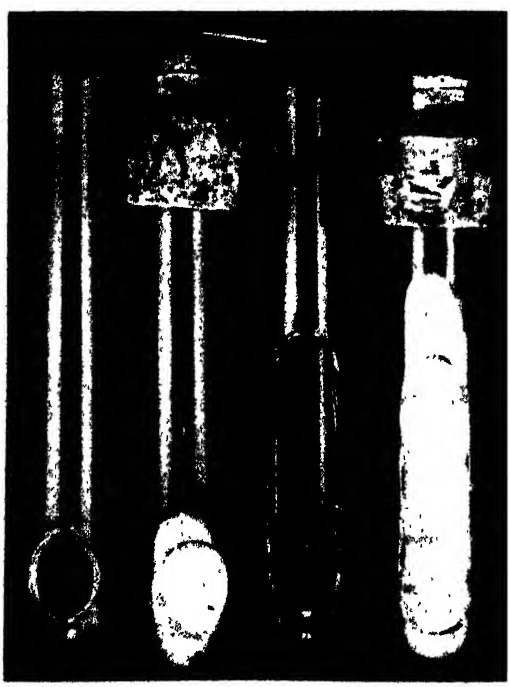
Adult Cages.

Adult flies are held in cages 12 × 12 × 12 in. built of 12 mesh galvanized wire gauze on a wooden framework with a sliding wooden floor. On one side is a small door and an aperture for insertion of feeding or oviposition tubes. (Fig. 1).

Feeding and Oviposition Tubes.

Feeding tubes used in cages containing flies for tests, were made from a design kindly supplied by the Brunswick Biological Laboratory of the Hercules Powder Company, United States of America. They consist of one inch diameter Pyrex test tubes with a feeding hole, approximately one inch in diameter near the base (Fig. 2a). Cotton wool is placed in the feeding hole (Fig. 2b) and the tube filled with liquid food. The tube is stoppered with a cork through which there is a bent glass tube allowing free soakage of food through to the surface of the cotton wool. A $1\frac{1}{2}$ in. diameter cork holds the tube in the cage.

Oviposition tubes are fitted in cages holding stocks of breeding flies and used for the dual purpose of feeding and oviposition. They are the same size as feeding tubes and have a large longitudinal aperture approximately four inches by one inch (Fig. 2c). The tube is prepared for use by filling the aperture with cotton wool, placing a cork stopper without tubing in the end (Fig. 2d) and filling the tube with liquid food. An oviposition tube prepared and in position is shown in Fig. 1.



A B C D

FIG 2 A. Feeding tube. B. Feeding tube prepared for food. C. Oviposition tube. D. Oviposition tube prepared for food. × ⅜. *Photo: R. I. Hughes*

FOOD

Larval Medium.

Larval food used is similar to the standard mixture recommended by the National Association of Insecticide and Disinfectant Manufacturers, United States of America (Anon. 1946). Materials available locally are used and the culture is prepared as follows :—

60 oz. dry mixture consisting of equal parts of wheat bran, lucerne meal and dried brewer's grains.

3,750 ml. aqueous suspension containing 75 g. yeast and 50 ml. malt extract.

These materials are mixed together and then divided equally into five breeding jars.

Adult Food.

Food for flies consists of milk powder, water and sugar. For breeding flies food is prepared according to the following formula, which provides sufficient food for three tubes :—

17.5 g. powdered whole milk, 200 ml. distilled water, 7.0 g. sugar.

For test flies the following formula is used, this amount being sufficient for four tubes :—

50 g. powdered skimmed milk, 300 ml. distilled water, 12.5 g. sugar.

To this last formula, 0.4 ml. formalin is added if food is to be used for a period exceeding 24 hours.

TECHNIQUE

Egg Production.

Four or more cages each with 500-700 adult flies are maintained for breeding purposes. Each cage is held for egg production for 14 days and is then replaced by a cage of newly emerged flies. Breeding flies are fed each morning with the appropriate food by means of oviposition tubes. After approximately 12 hours the food has dried sufficiently to present a suitable site for oviposition. Eggs are rarely laid before this time and consequently the majority of eggs collected are under 12 hours old.

Other methods of obtaining eggs have been tried but discarded for various reasons. In one method a petri dish containing milk-soaked cotton wool or freshly prepared larval medium was placed within each breeding cage. This gave a satisfactory number of eggs but had the disadvantage that flies escaped when a dish was being passed through the door of the cage.

Another method made use of the feeding tube which can be inserted into and removed from the cage without escape of flies. It was observed that some eggs were deposited on the cotton wool in the feeding tubes in cages holding test flies. These tubes were tried as oviposition sites in breeding cages but results were not satisfactory because the cotton wool was always too moist for oviposition.

Eggs are taken from oviposition tubes each morning, placed in water and 0.3 ml. of eggs pipetted off. These are run with 10 ml. water into a shallow pit on top of the medium in each larval breeding jar.

Larval Breeding.

The larval medium is prepared on the afternoon of the day before eggs are transferred and then divided out into jars and placed in the breeding room overnight. Five breeding jars are prepared each day. Larvae pupate in numbers on the sixth day and pupae are taken from the culture on the ninth day, by which time all larvae have pupated.

Separation of Pupae.

Separation of pupae from a culture in a clean condition is desirable in a fly-breeding programme because at this stage flies are most easily handled, counted and distributed to cages.

The following method has proved to be most satisfactory for this purpose.

Before eggs are transferred, a petri dish $3\frac{1}{2}$ in. diameter and $\frac{1}{2}$ in. deep, containing a flat pad of moistened non-absorbent cotton wool completely covering the bottom of the dish is buried one half-inch beneath the surface of the medium. On the fifth day, when pupation commences, larvae work their way through the cotton wool which is apparently more attractive at this stage than the larval medium. During this activity the wool becomes fluffy, rises to the surface of the medium and within two days attains the size of a tennis ball (Fig. 3a). A few larvae may pupate in the wool but the majority pupate in the dish beneath (Fig. 3b). On the ninth day the cotton wool is lifted away and the petri dish, now full of pupae, removed from the culture jar. Pupae from the five petri dishes of one culture are mixed, counted (by weight) and distributed to cages for emergence.

A B

FIG 3.—Larval medium jars at ninth day A. Showing fluffy cotton wool pad on surface. B. Cotton wool removed showing petri dish full of clean pupae beneath. × ¼. *Photo: R. I. Hughes*

Pupae obtained in this way are exceptionally clean and in a polished condition with little if any of the culture medium present. The whole process of collecting and sorting pupae takes only a few minutes, and pupae are not injured by any lengthy separation process. A few pupae remain in the medium but these are discarded as too much time is involved in collecting and cleaning.

Over a period of several months it has been noted that from 60 to 90 per cent. of pupae are collected in dishes. Thus from five jars of a single culture between 4,000 and 5,000 pupae were regularly obtained and these were sufficient for one day's requirements.

It has been found that much of the success of this method depends on correct preparation and placement of the petri dish. Dishes should be buried at least ½ in. to allow for sinking of the medium. They should be placed quite level, otherwise dishes will be only half full or empty at separation time. Non-absorbent is preferable to absorbent cotton wool while the pad should be well wetted with water and cover the bottom of the dish to a depth of ⅛ in.

Many methods for separation of pupae have been described and Basden (1947) lists the majority of them. Several methods depending on the drying of the medium and its subsequent separation from pupae by means of air currents have been tried in this laboratory with varying degrees of success. With all methods investigated, however, a considerable amount of time was necessary for the process. Other undesirable features, and ones which could result in injury to pupae, were that they were handled considerably; they were exposed to drying air currents and were unavoidably shaken about during winnowing or sieving processes.

Adult Feeding.

Emergence of adult flies begins on the tenth or eleventh day after a culture is commenced and peak emergence occurs on the fourteenth day. Adults are fed on the appropriate food mixtures each morning. Over a week-end period both test and breeding flies are fed with the skimmed milk powder formula plus formalin. One feeding tube is sufficient for approximately 500 flies for this period.

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REVIEW

PRACTICAL ASTRONOMY

By J. J. NASSAU, Professor of Astronomy, Case Institute of Technology. Second Edition. Pp. 311 + xii. McGraw-Hill Book Company Inc. 1948. $5.

THE mathematical problem in determining time, latitude and azimuth lies in the solution of a spherical triangle formed by the elevated pole, the zenith and the celestial object, having given the requisite number of elements. The practical problem of the astronomical surveyor is the determination of some of these necessary elements, which usually resolves itself into a measure of the zenith distance together with the observations of time and horizontal angles as required.

Simple though the mathematical requirements may be, the surveyor is concerned intimately with his instruments, error corrections, theoretical conditions for the best type of observation and the best form of solution for the triangle. The fundamental problems and their practical solutions are old and belong to the classical portion of astronomy. Modern approaches are concerned with finer instruments, improved methods of observation and the tabulation of astronomical data in almanacs.

This new edition of a standard work is considerably enlarged and re-written, so as to cover all the classical requirements as well as the modern improvements. In the latter respect the lack of stress on sidereal time in in comparison with the Greenwich Hour Angle is notable in view of the coming change in the 1950 edition of the British Abridged Nautical Almanac, although this has been tabulated for some years in the American Nautical Almanac.

Another notable and highly praiseworthy feature of the work is its division into two parts determined by the accuracy of the instruments used. The first part, after dealing with the astronomical concepts involved, gives the methods of observation and computation for instruments having a reading accuracy of about 0.1 minute of arc. Quite correctly, five places of values are used as being sufficient for the reductions. Also the American Nautical Almanac, corresponding to the British Abridged Nautical Almanac, is considered to give the astronomical data to the necessary degree of accuracy. In the second part more precise determinations are considered, using finer theodolites for azimuth, zenith telescopes for latitude and astronomical transits for time, with the corresponding different methods for reduction. Here the use of standard almanacs giving precise quantities and the method of using them is given. Astrobales for time and latitude conclude this section, which can be taken as a good introduction into field geodetic surveying.

Being an American production, all references are naturally to American almanacs. This need be no bar to its successful use by beginners in this country, however, so long as it is realised that the American use of 'civil' time corresponds to the English usage of 'mean' time. The reviewer feels that the method of defining and dealing with azimuth is a little clumsy, although this is due in part to the fact that astronomers have no universal definition (*vide* Chauvenet and other works). Consideration of the astronomical triangle would seem to indicate that 'azimuth' is not necessarily synonymous with 'bearing' as defined by navigators.

Little, if any, criticism can be found for this excellent work, which will be found useful for reference purposes as well as initial study. In some sections slight differences in fine detail between American and New Zealand practice may be noticed by experts. Otherwise the book is very suitable for self-tuition, with plenty of sensible problems and answers. Such a work should form part of the equipment of those concerned with general astronomical surveying.

The usual high quality of production by McGraw-Hill has been maintianed.

—I. L. T. 23 June 1949

THE NEW ZEALAND

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Editor: N. A. Marris, M.Sc., B.Com. (Assistant Editor: M. O'Connor, M.Sc.)
Department of Scientific and Industrial Research, Wellington

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GROUND WATER IN NORTH CANTERBURY, BETWEEN THE WAIMAKARIRI AND ASHLEY RIVERS

By B. W. COLLINS, New Zealand Geological Survey.

(Received for publication 10th June, 1948)

Summary

High ground water levels adversely affecting farming during recent years in part of North Canterbury are ascribed mainly to exceptionally high rainfall throughout the preceding ten years. Deterioration of the drainage system, cultivation and changes in vegetation, and aggradation of the river-beds may also have tended to raise the water table. Sources and conditions of occurrence of ground water in the district are discussed, with particular reference to a drainage scheme proposed by the North Canterbury Catchment Board.

INTRODUCTION

PROBABLY the first written description of the Canterbury Plains is that of William Barnard Rhodes, elder brother of George Rhodes, of the Levels Station in South Canterbury, who in July, 1836, climbed the Port Hills from Lyttelton (then Port Cooper) and recorded in his diary: "I saw the Plains and two pieces of bush. All the land that I saw was swamp and mostly covered with water."

A realization of the deep fertile soil to be made available by artificial drainage of the swamp areas of Canterbury was a major factor in the settlement of the province. Many districts, of which the eastern part of the area to be described in this report was one, were drained early in the history of Canterbury; and at the present time many of the most productive farms in the province are to be found on areas that before the advent of Europeans were boggy, almost impenetrable wastes of flax and raupo.

During the last few years much of the drained land has been deteriorating through an excess of underground water, and at the same time much damage has been done by surface flooding. A combined drainage and flood-control scheme for the plains area between the Ashley and Waimakariri Rivers in North Canterbury has been devised by the engineer of the North Canterbury Catchment Board, and the geological aspects of ground water as they affect this scheme are considered in this report.

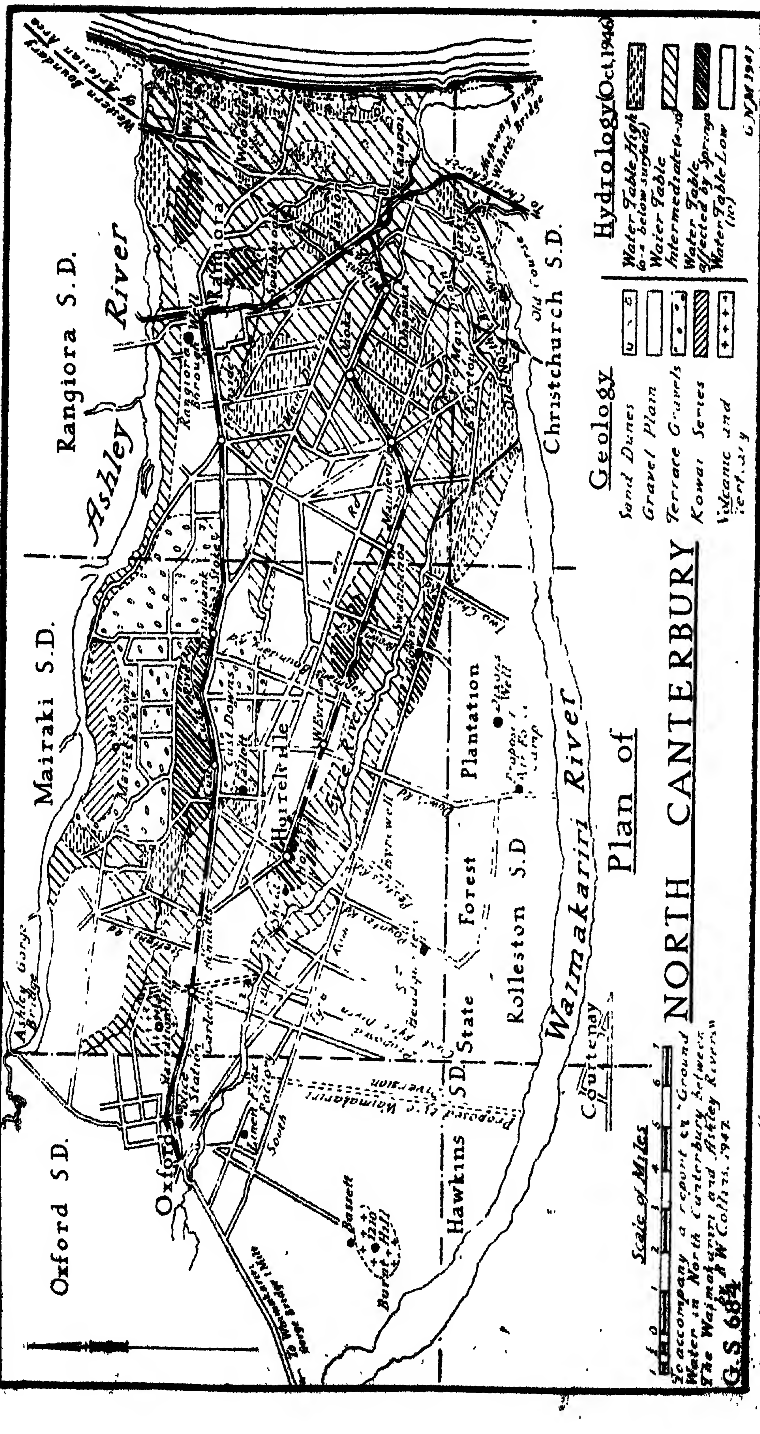
Plan of
NORTH CANTERBURY
Oxford S.D.
Mairaki S.D.
Rangiora S.D.
Christchurch S.D.
Hawkins S.D.
State Forest
Plantation
Rolleston S.D.
Courtenay
Ashley River
Waimakariri River
Oxford
Rangiora
Kaiapoi
Ashley Gorge Bridge
Geology
Sand Dunes
Gravel Plain
Terrace Gravels
Kowai Series
Hydrology (Oct 1946)
Water Table High
Water Table Intermediate
Water Table affected by Springs
Water Table Low
Scale of Miles
G.S 684

FIG. 1

GEOLOGY

For a brief geological description of the area, the following units may be distinguished (Fig. 1):

(1) *Burnt Hill and Starvation Hill:* At Burnt Hill (1,210 ft., about 400 ft. above the general surface of the plain), six miles south of Oxford, there exists a remnant of the old surface on which were deposited the alluvial gravels of the Canterbury Plains. Still unburied because of its elevation, this hill consists of an inlier of Tertiary sediments capped by basalt. A similar occurrence of volcanic rock forms Starvation Hill (943 ft., about 250 ft. above the plain), some three miles east of Oxford. Magnetic surveys on the Canterbury Plains (Jones, 1942) have indicated the probable existence of other masses of volcanic rock buried beneath the surface. It is probable that masses of relatively impervious rock of this kind impede the free seawards flow of ground water.

(2) *The Mairaki Downs:* Between Cust and the Ashley River the Mairaki Downs rise to 936 ft., or 500 ft. above the surface of the plains. On the north and northeast sides, the Mairaki Downs are dissected by many deep gullies, exposing good sections of the beds of which they are composed. These consist of sandy gravel and clay, brown through oxidation and fairly well cemented. They are tilted towards the east-northeast up to 12°. These gravels, obviously older than those of the plains, are probably to be correlated with the Kowai Series of Speight (1919) and may be Waitotaran in age (Mason, 1941). Because of their greater compaction and cementation compared with the younger gravels of the plains, these beds must be much less permeable. Mr. H. W. Harris, engineer to the North Canterbury Catchment Board, estimates, in fact, that the run-off from this area approximates to 90 per cent. It is probable that these older, oxidized, and compacted gravels underlie the Canterbury Plains in other areas, perhaps at no great depth (they are exposed, for instance, at Rakaia Gorge), and form a relatively impervious surface on which ground water collects. This may be a factor in keeping the water table high in some places.

(3) *The Cust Downs:* On the south side of the Cust River, opposite the Mairaki Downs, beds of gravel and sandy clay compose an area of rolling country 30 to 50 ft. higher than the general surface of the plains. The strata are similar in composition, cementation, and compaction to the older tilted gravels of the Mairaki Downs, but retain, however, an almost horizontal attitude, parallel to the surface slope of the country. The Cust Downs are bounded to the north and south by a definite terrace about 20 ft. high near the middle and gradually decreasing both east and west, in which directions the downs merge into the general surface of the plains.

On the north side of the Cust Valley similar beds overlie the tilted gravels on the lower parts of the Mairaki Downs and form a relatively flat belt of rolling country almost surrounding the higher hills.

The surface of both the Mairaki and Cust Downs is covered with yellow silty clay almost identical with the loess of Banks Peninsula. On the lower parts of these areas the presence of occasional small pebbles in this deposit indicates that it has in places been reworked by streams.

(4) *The Canterbury Plains Proper:* The greater part of the area here considered, between Oxford in the west and a line joining Fernside and East Eyreton in the east, is composed of an extensive series of beds of sandy gravel with various proportions of clay, mostly very porous and permeable, some relatively impermeable, but none appreciably cemented. These beds have been formed as the sub-aerial parts of the great confluent deltas built out by the rivers issuing from the mountains to the west. The surface slope of the plains in the direction of maximum gradient (from the Waimakariri Gorge to Lake Ellesmere) averages 34 ft. per mile, but it is steeper towards the hills in the west and gentler on the lower parts of the plains toward the coast.

(5) *The Coastal Lowlands:* In the districts around Rangiora and Kaiapoi the present surface consists mainly of sand, silt, and peat deposits, which, as revealed in the logs of wells drilled in the area, are interbedded with gravels to a depth of at least 450 ft. Oscillations of sea-level during an extended period of general submergence were probably the cause of this sedimentary sequence. Towards the east of this belt of country, at a distance of from two to four miles from the sea, the present surface is only a few feet above sea-level. In the west the boundary between the marine and alluvial silts, sands and swamp deposits and the alluvial gravels of the plains is very irregular, tongues of gravel representing old infilled stream channels extending sinuously eastward into the lowlands.

(6) *The Present River Beds:* Where the main rivers of Canterbury debouch from the mountains they have cut down into their fans to form deep canyons with steep, terraced banks up to several hundred feet below the fan surface. The banks of the Waimakariri gradually diminish in height from about 200 ft. at the Gorge to a point about 15 miles from the sea. Further downstream the bed is almost level with, if not actually higher than, the neighbouring part of the plains; and if the river were not controlled by stop-banks, in flood time it would find its way into old, abandoned channels—for example, the Old North Branch leading through the township of Kaiapoi, or those leading southeast towards Christchurch. The bed of the Waimakariri is of variable but generally great width (in places more than a mile, even under present conditions of artificial constriction), and consists predominantly of greywacke gravel, the average size of which gradually diminishes from the foothills to the sea. In the lower parts of its course banks of sand and silt are present. During periods of normal or low flow the bed is intersected by numerous irregular, anastomosing streams. During floods, however, caused by heavy rain in the mountainous catchment area (usually from the northwest), the water may extend from bank to bank and even overflow the low-lying land on either side.

The grade of the Waimakariri is considerably less than that of the plains in its neighbourhood; from the Gorge bridge to a point about 10 miles from its mouth it is 27 ft. per mile. From this point it gradually flattens to the sea.

The Ashley and Eyre rivers present similar features on a smaller scale. Unlike the Waimakariri, which has a perennial flow, both these rivers are intermittent, though the Ashley is rarely dry. The Eyre River, on the other hand, in years of normal rainfall, has for months at a time no water flowing above the surface in the lower part of its course. It is frequently asserted that the Eyre River flows on a ridge some feet higher than the plains on either side. Such contour maps as exist, however, show no

indication that this supposed ridge exists. It is true that the banks of the Eyre are of no great height, and in heavy flood the river is liable to overflow and inundate adjacent land. The lower part of the Cust River appears to lie in a slight depression between the fans built by the Ashley and the Eyre. It has been so much altered by man for purposes of drainage during the last hundred years that, at the present time, it has for much of its course more the appearance of a "Main Drain", by which name it is in fact known. Extensive areas of the Upper Cust Valley between Oxford and the township of Cust are still swampy. Before artificial drainage of the area was undertaken the Cust and Eyre flowed into the swamps of the coastal lowlands and had no direct outlets to the sea.

(7) *The Sand Dunes:* A coastal strip two miles wide, between the mouths of the Waimakariri and Ashley, is made up of ridges of beach shingle and sand. Only near the coast are the dunes free to move; further inland they are fixed by vegetation. These dunes rise 25 ft. above sea-level. Swampy hollows lie between the various ridges and also on the inland side of this zone.

On the accompanying map (Fig. 1) unit (1) is called "Volcanic and Tertiary"; unit (2), "Kowai Series"; unit (3), "Terrace Gravels"; units (4) and (5) have been grouped together as "Gravel Plain"; unit (6) is indicated merely by the topographic lines showing the river banks; and unit (7) is shown by conventional dune symbols.

GROUND-WATER LEVELS

During October and early November, 1946, and again for a few days in February, 1947, observations were made of the depth of the water-table. Information was obtained from gravel pits deep enough to intersect this surface, from public and private wells, and from springs and other natural hollows. Residents and local-body officials were consulted in order to gain as much knowledge as possible of the fluctuations in the level of the water table.

In general, it may be stated that in most parts of the area the water table is fairly close to the surface. Near Oxford a well drilled at the Linen Flax Factory in 1941 obtained water 48 ft. below the surface. At the Oxford Police Station in 1944 the water level in a well was 25 ft. below the surface. As the driller's logs of both these wells record only "shingle" (gravel), it may be inferred that the water referred to was not under pressure beneath a confining bed, and hence the depths given are those of a free water surface or water table.

Further east, in the central and eastern parts of the area, the water table is nearer the surface; in fact, in the region of Rangiora, Ohoka, and Kaiapoi, it formerly was practically coincident with the land surface, and the district was a swamp. Artificial drainage subsequently lowered the water sufficiently for farming, but in recent years there has been a tendency for the water to rise again and interfere with agricultural operations.

In the southern part of the area, between Burnt Hill and the Two Chain Road, the water table is at a considerable but undetermined depth. A well drilled to a depth of 133 ft. on Mr. C. F. Bassett's property near Burnt Hill in 1928 was abandoned, it being stated in the driller's log that there was "no supply." The water level is, however, recorded as 67 ft.

below the surface. At the proposed Air Force Camp near Eyrewell, 5½ miles south of West Eyreton, a well was sunk 171 ft. in 1942 without striking water. Two miles east by north of this point an open well had been dug some 50 years ago by Mr. R. Dixon to a depth of 100 ft., also without success. Further east again, near the present Eyre Diversion, the water table is within a few feet of the surface; and the country is swampy in places. Here the bed of the Waimakariri is approximately at the same level as the plains' surface, and the water level underground is apparently related to that in the river.

Ground-water conditions in the area for October, 1946, are indicated on the map accompanying this report (Fig. 1) by ruling superimposed on that indicating the geology. The water table is lower (more than 10 ft. below the general surface) in all areas of volcanic and Tertiary rocks, gravels of the Kowai Series, and terrace gravels, as well as the western part of the gravel plains. In these areas artificial drainage of ground water is unnecessary. The areas in which the water table was high (within 4 ft. of the surface) are shown by horizontal dashes. Most of these areas were parts of the original swamps, and all need further drainage. An intermediate water table (4 to 10 ft. below the surface) is indicated by two types of diagonal ruling. Those areas where springs or seepages rise in hollows and cause trouble through surface flow of water or water-logging of the soil are ruled in alternate thick and thin lines. Provision for the disposal of this water is required to prevent loss of production on the farms immediately concerned as well as flood damage lower down on the plains. Thin diagonal ruling shows the districts where the water table, although relatively close to the surface, causes, so far as was observed, little or no damage.

Three sections showing the relation of the water table to the ground surface in October, 1946, are presented (Fig. 2). It is to be noted that the vertical scale in these sections is greatly exaggerated, and that both the horizontal and vertical scales of section 1 are only half those of the other two sections.

FLUCTUATIONS OF THE WATER TABLE

During the past 25 years (as far back as it is possible to go with the records available at present), according to information gathered from residents, there have been remarkable variations in the ground-water level, especially in some districts. On Mr. C. H. Tallott's farm, for instance, about a mile south of Cust, where the water table last November (1946) was within three or four feet of the surface, a well 28 ft. deep has been known to go dry several times. On a neighbouring farm (Cowan's), an open well 60 ft. deep is said to have been dry occasionally. At Horrelville several wells are about 30 ft. deep; some have been dry at times, but in others the water level is said to remain fairly constant, varying only a few feet even in extremely wet or dry seasons. Statements such as this last, however, cannot be accepted without hesitation; it may be that those wells that have never gone dry are deeper than those that have. On the other hand, in parts of the area here considered, the composition of the surface and the subsurface deposits of the plains is so variable within short distances that it is possible that wells quite close together are supplied from different sources, and their fluctuations may not be readily correlated.

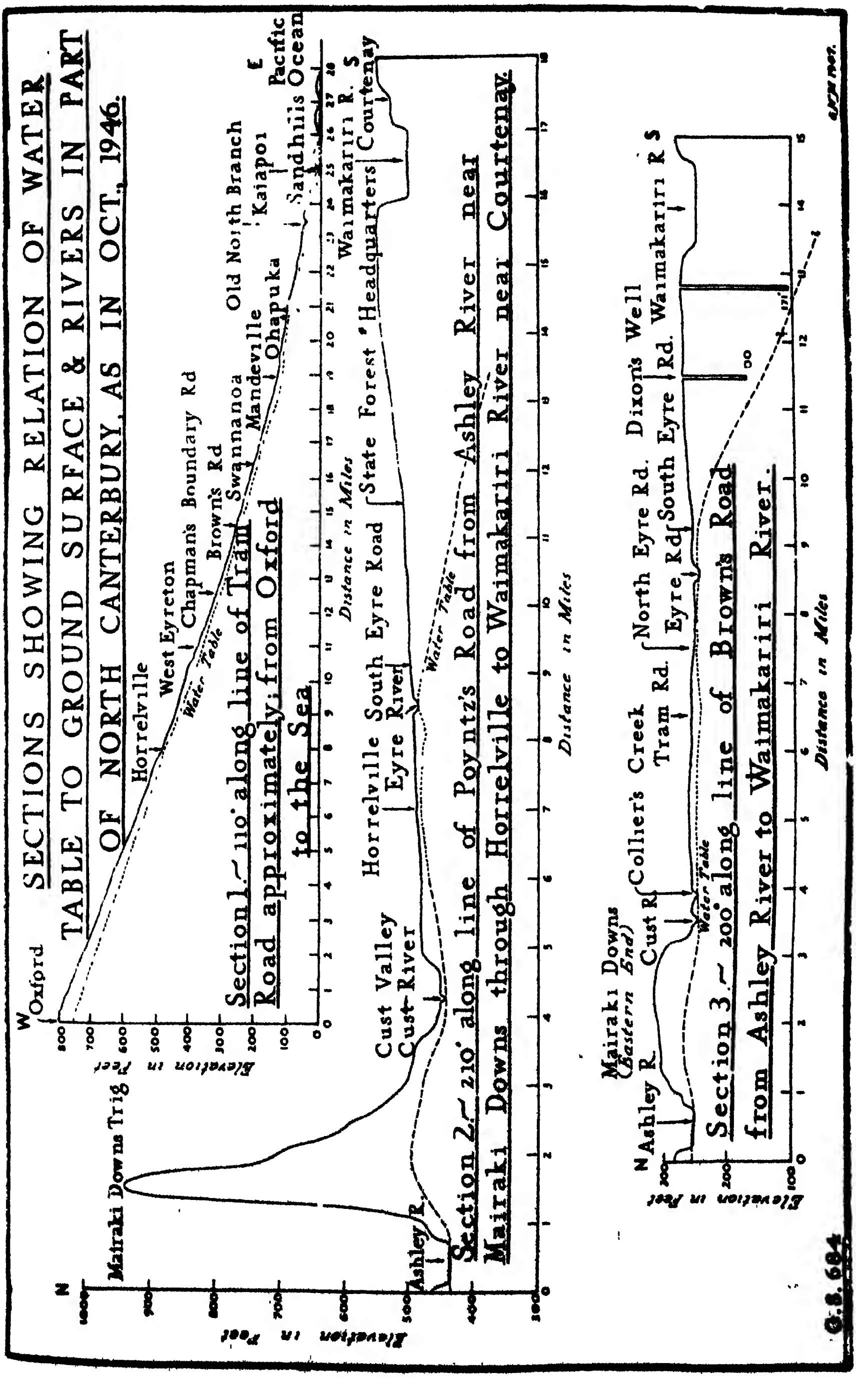
SECTIONS SHOWING RELATION OF WATER TABLE TO GROUND SURFACE & RIVERS IN PART OF NORTH CANTERBURY AS IN OCT., 1946.
Section 1. ~ 110' along line of Tram Road approximately from Oxford to the Sea
W Oxford
Horrelville
West Eyreton
Chapman's Boundary Rd
Brown's Rd
Swannanoa
Mandeville
Old North Branch
Ohapuka
Kaiapoi
Sandhills
Pacific Ocean
E
Water Table
Elevation in Feet
Distance in Miles
Section 2. ~ 210' along line of Poyntz's Road from Ashley River near Mairaki Downs through Horrelville to Waimakariri River near Courtenay
N
Mairaki Downs Trig
Ashley R.
Cust Valley
Cust River
Horrelville South Eyre Road
Eyre River
State Forest Headquarters
Waimakariri R. S
Courtenay
Water Table
Elevation in Feet
Distance in Miles
Section 3. ~ 200' along line of Brown's Road from Ashley River to Waimakariri River.
N Ashley R.
Mairaki Downs (Eastern End)
Cust R.
Collier's Creek
Tram Rd.
North Eyre Rd.
Eyre Rd.
South Eyre Rd.
Dixon's Well
Waimakariri R. S
Water Table
Elevation in Feet
Distance in Miles
G.S. 684

FIG. 2

Mr. M. Spencer Bower's well, two miles east of Eyrewell, near Brown's Road, was deepened in 1934 to 60 ft., at about which depth water was met. It has never been dry since, and the water level now stands about 7 ft. below the ground surface. Mr. Bower states that the water table was high in 1924, and that it was not so high again until 1945. This agrees with statements of Messrs. Tallott (high 1923–25) and J. Horrell (high in autumns of 1925 and 1936).

There is general agreement that the average ground-water level throughout the year has been tending to become higher since 1944, and has seriously interfered with farming. A high water table in spring is more or less to be expected and may pass unnoticed, but in the last few years the level has been high in summer and autumn and has hindered (and sometimes prevented) such important farm work as harvesting or sowing of autumn wheat.

The close correspondence between the height of the water table and the rainfall in North Canterbury is obvious when the statements in the last few paragraphs are compared with the annual rainfalls presented in the graph (Fig. 3). Rangiora is near the centre of the eastern half of the area, and rainfall records from this locality would be especially informative. Such records, unfortunately, are available only until 1939. It is apparent from the graph, however, that the records for Christchurch (16 miles to the south) are closely similar, and comparison of these also

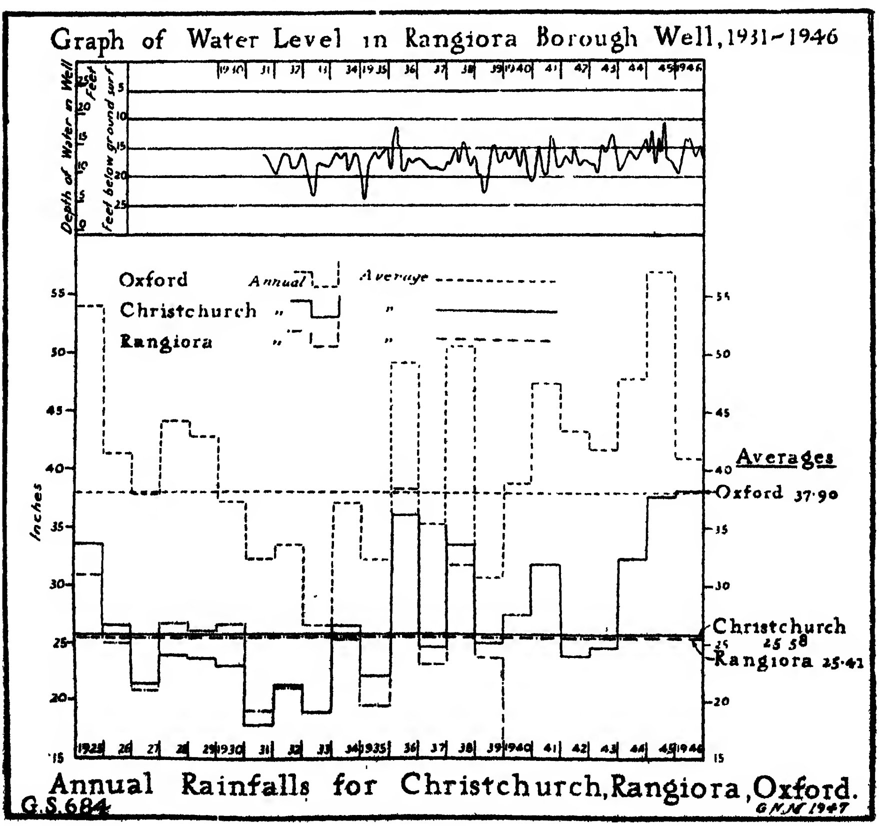

FIG. 3

with those for Amberley (about 12 miles northeast of Rangiora) shows that the Christchurch records may be taken as fairly representative of the rainfall on the eastern half of the area concerned. Towards the west the rainfall increases until at Oxford (20 miles west of Rangiora) it is, on the average, 50 per cent. greater. The years 1925, 1936, 1938, 1941, and 1944–46 were years of very high rainfall at Oxford, Christchurch, and (as far as the records go) also Rangiora. Several of these years were noted for the high level of ground water. The unusual combination of three consecutive years of high rainfall (1944–46) is obviously the main reason for the excessively high water table experienced recently—whether the ground water is supplied mainly by percolation or rainfall vertically or by leakage laterally from streams and rivers.

The relation between rainfall and ground-water level may be studied in greater detail by comparing the monthly rainfall records for 1945 and 1946 with the static water level in the Rangiora Borough's 36 in. well, records of which have been kept almost daily since it was completed in August, 1931, by Mr. H. H. Matthews, borough electrical and waterworks engineer (see Fig. 4). It will be observed that the water level fluctuates in general agreement with the rainfall without any appreciable time lag. Closer inspection of the records shows that the level usually begins to rise 5 to 9 days after the beginning of significant local rain, continuing to rise for 8 to 17 days after the rain has stopped. This seems to indicate that the ground water in this locality is, to a large extent at

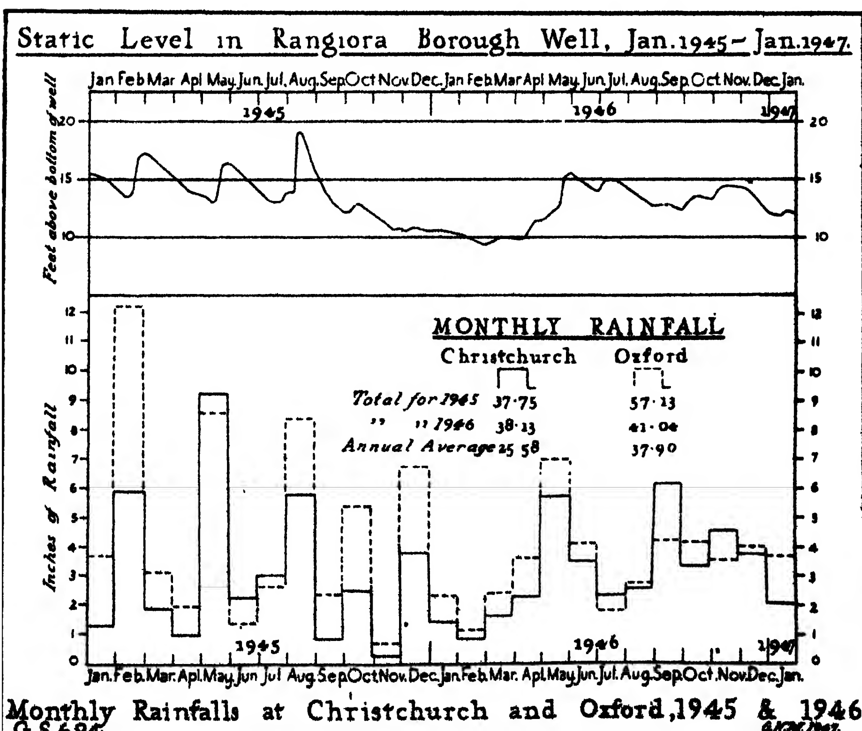

FIG. 4

least, fed directly from rainfall, though, of course, it must also be supplied by the slow movement seawards of the water that has percolated to the water table further west on the plains. It is to be noted that the highest level since 1931 was recorded in August, 1945; the lowest in February, 1935.

The rainfall at Oxford (shown on the graph, Fig. 3) may affect the level in this well for some time after local rain has percolated to the water table or been retained in the soil. The time during which this effect may be felt is discussed below. The level in the well has been observed to rise after floods in the Waimakariri (indicating rain in the hills) even without rain at Rangiora. If this observation is correct it may be inferred that some ground water is supplied by leakage from the bed of this river. On the other hand, although the Ashley is within a mile of the well, it is thought by Mr. Matthews that variations in the flow of the Ashley have little or no effect on the well-water level.

When observed again in mid-February, 1947, ground-water levels in many parts of the district had receded two to five feet below the October levels. According to the local farmers, the water table, which had been rising for some months, reached its peak about the end of November, 1946, since when it has declined, although rains in January and early February had caused temporary rises. The contrast between the ground-water conditions in the summer and autumn of 1946–47 and those of 1945–46 (when the level was excessively and inconveniently high) may be accounted for by the different distribution of rainfall in the two years (1945 and 1946), and also by the fact that although the rainfall at Christchurch for 1946 was a record high figure, that at Oxford for the same year was very much lower than that in 1945—in fact, the lowest since 1940.

SOURCE OF GROUND WATER

In addition to that supplied by direct percolation of rainfall to the water table, ground water in the area may receive supplies from other sources. Since the water table is in general a sloping surface with a gradient not very much less steep than that of the plains (30 to 35 ft. to the mile in the area between the Ashley and Waimakariri) and the gravels and associated beds of the plains are generally very porous (especially towards the west of the area where, according to well logs, clays are absent or rare), there must be considerable underground flow of water toward the sea (see section 1, Fig. 5). The actual rate of movement of ground water, even in very permeable beds, is usually not more than a few feet a day, but what is of importance in this connection is the rate of movement of the wave on the surface of the water table (water-table peak or phreatic wave). From observations in Ashburton County in similar gravel beds R. L. Oliver in 1946 concluded that this wave moved at the rate of about 170 ft. a day. In permeable basalt in Idaho (Meinzer, 1942) such a water-table peak has been found to move at an average rate of 750 ft. a day. Assuming that the rate in North Canterbury is about 200 ft. a day, the time necessary for a water-table peak to move from Oxford to Rangiora (20 miles) would be about 18 months. This is in fair agreement with the experience of local farmers who have noticed that the ditches in the Ohapuku district (near Kaiapoi) are 18 to 24 months "behind the season." Superimposed on this source of fluctuation of the water table are fluctuations due to local rains, which are more rapid and often of greater range and hence tend to obscure the relations.

A further source of ground water that must be considered is lateral seepage from the rivers. Many farmers are convinced that the water level in their wells fluctuates with the flow in a nearby or even somewhat distant river—in the latter case generally the Waimakariri. Some even say that subsequent to a river becoming cloudy in a flood their well water becomes milky. This may be due to contamination of the well by muddy surface water, as many such wells are quite unprotected from the inflow of surface water, while some are situated in hollows that collect surface run-off after rain. In a narrow strip of country on either side of the Eyre, between Horrelville and the present diversion, the water table is at present fairly close to the surface and springs rise in low parts in wet seasons. These springs, and the water level in wells, are thought by residents to fluctuate in sympathy with the flow in the Eyre. The effect is most rapid near the river, and the time lag increases with increasing distance. Mr. Sheat's well (a mile southwest of Horrelville and a quarter of a mile from the river) is said to rise 24 hours after a flood in the Eyre. Mr. J. Horrel's well (at Horrelville, a mile and a half from the river) begins to rise 10 days after a flood; with a rising river, further rain is said to affect the water level within 24 hours. About two miles northeast of Horrelville, on Mr. Tallott's property, the water table is stated to rise a month later than at the former locality, and to remain high from one to two months longer. On and near Mr. Spencer Bower's farm, near Eyrewell, no springs rise on the slightly higher ground immediately south of the river—the soil in this strip is a fertile silt loam derived from former flood deposits of the Eyre River—but on the stony country further away from the river, many springs have been flowing almost continuously for the last two years. (During this time also there has been an unprecedented continuous flow in the Eyre, normally dry in this part of its course for the greater part of each year.) The water level in Mr. Bower's well (half a mile south of the river) is said to rise two weeks after the Eyre flows in this locality.

From facts such as those given above and others of a similar nature—even allowing for some erroneous observations—it seems probable that some of the ground water in the district is supplied by the Eyre River, and the water table may be thus affected several miles from the river. In the lower part of its course (from Oxford to its junction with the Waimakariri through the present diversion) the Eyre normally flows only intermittently, and there may be a surface flow in parts of its bed with no visible water in sections both above and below. On October 16, 1946, for instance, it was flowing through the diversion, and at Downs Road, dry at Pester's Road and Poyntz's Road, and flowing strongly at Steffen's Road. It may thus be described as a spring-fed intermittent stream (Meinzer, 1923) its flow being affected by fluctuations in the water table whereby the stream channel stands in various places at times above and at other times below the water table. The influence must be in both directions, however, and after heavy rain surface water flowing down the Eyre must help to build up the water table lower down on the plains as it seeps away through the bed of the river.

On the upper part of the plains the Ashley and Waimakariri are both deeply entrenched, and land adjacent to them is not affected by a high water table. Moreover, information as to the depth of ground water is lacking because of the absence of wells. Unless the rivers are insulated

from the water table it appears that ground water must contribute to their flow, since the elevation of the water table at Oxford and Burnt Hill (on rather meagre information) is well above that of the water level in the Waimakariri at an equal distance from the sea. For the middle part of the course of the Waimakariri through the plains information is more definite. The experience of well-sinkers in the area of the Eyrewell State Forest, as mentioned previously, has shown that the water table in this district is more than 100 ft. below the level of the river. The lack of a water supply for wells here cannot, in the opinion of the writer, be due to lack of permeability or to a negligible specific yield of the strata penetrated. The soils of the State Forest area are classified by the Soil Bureau as very light, stony, sandy silt loams of very low fertility and very dry (C. S. Harris, personal communication). The gravels underlying the area must also be very porous and pervious, since, in spite of a considerable rainfall (averaging 43.5 in. annually at the State Forest Headquarters during 1942–46), there is no surface run-off from this area whatever, and the entire rainfall (apart from that evaporated and transpired by plants) must percolate down to the water-table. The only reasonable explanation of this situation seems to be that in this part of its course the Waimakariri has deposited sufficient silt and clay in the gravels forming its bed to render it impervious and hence insulated from the water table.

Steam-gauging records for the Waimakariri are not at present sufficiently accurate to enable a definite conclusion to be reached as to whether or not there is any leakage from the river over this stretch. A series of comparative records obtained by the engineers of the former Waimakariri River Trust is as follows:—

Gorge Bridge	White's Bridge
1,700 cusecs	1,650 cusecs
4,500 ,,	4,200 ,,
10,500 ,,	10,200 ,,
41,000 ,,	40,700 ,,

The differences shown are probably within the limits of error of the methods used, but so far as they go the records show only a very slight decrease in volume over the 30 miles of riverbed between the gauging stations. Benson (1946) noted that all these records refer to periods of relatively low flow, and stated that during periods of higher flow the measured losses have been greater. At the same time, however, the limits of error would be greater. Some of this loss is to be accounted for by water drawn off in water races, and a further part may leak away from the river in the lower part of its course (near East Eyreton), where the water table is known to be close to the surface and approximately at the same level as the river. The conclusion to be drawn from the existing records of stream flow, therefore, is that if there is any loss from the Waimakariri in the middle and upper part of its course through the plains, the amount is very small.

A copy of the log of the well drilled at the proposed Air Force Camp near Eyrewell was kindly supplied by Mr. S. Taylor, of Job Osborne and Co., well-sinkers, Christchurch.

EYREWELL CAMP (3in. well)

Depth—	171 ft.	No water. Abandoned.
	0– 14 „	Brown shingle (hard) cemented with clay.
	14– 18 „	Brown shingle (open).
	18–171 „	Brown shingle (hard), as above.

—H. Tucker, 22/10/42.

Mr. Taylor informed the writer that nearer the river, about a chain from the terrace edge, another well was then put down to about 100 ft. The same strata were penetrated and no water obtained. A third well was sunk in the riverbed itself about 30 ft. from the toe of the terrace, a fourth half-way between the terrace and the main stream of the river, and a fifth about 10 yds. from the running water. Only in the last well was any water struck, and this was only a slight seepage from seven feet below the surface and considerably below the level of the water in the river.

The district south of the Waimakariri opposite the Eyrewell State Forest has not yet been investigated; but an indication that conditions are similar (i.e., very deep water table insulated from the river) is given by the statement of Mr. A. B. Clemence, proprietor of J. W. Horne and Co., well-sinkers, Christchurch, that at Darfield (eight miles south of Burnt Hill) an open well 200 ft. deep was dry. The diggers could not continue the well because of foul air; but a pipe was driven by Mr. Clemence to 230 ft., and the water stood at 210 ft. below the surface. The banks of the Waimakariri in the neighbourhood are 100 ft. high.

DRAINAGE

(1) *Natural Drainage:* The Canterbury Plains, being relatively young, had in their natural state a very inadequately developed drainage system. Only the extended consequent rivers, flowing across them from the mountains to the west, had eroded their beds any appreciable depth below the ground surface. Even some of the smaller of these, such as the Eyre and Cust in North Canterbury, although draining considerable areas of foot-hill country, flowed in ill-defined beds with low banks very nearly at the same level as the general surface of the plains. Only in places where marine erosion had developed a cliff at the coast had streams originating on the plains themselves developed by headward erosion channels of any great depth. Since the climate is sub-humid near the coast, changing to humid and then wet as the mountains are approached, it is not surprising that in those districts between the incised drainage channels and towards the coast where even the main rivers are not greatly incised, the water table is relatively shallow and swamps are common. This situation may have been aggravated also by the gradual subsidence of the land with respect to the sea, evidence for this movement being provided by the drowned topography of Banks Peninsula, and by the occurrence of beds of peat down to depths of 700 ft. below the present surface in the Christchurch area, as revealed in drilling artesian wells. Professor R. Speight (1917) has suggested that a rise in the water table with consequent water-logging of the soil, brought about by subsidence of the land, may have been the cause of the destruction of the forests that flourished in fairly recent times on the eastern Canterbury Plains.

"In the swampy areas round Lakes Ellesmere and on the low-lying eastern fringe of the plain there existed [when Canterbury was first settled by Europeans] a great amount of timber, chiefly white pine, or kahikatea *(Podocarpus dacrydioides)*, and manuka *(Leptospermum scoparium)*, some of which lay prone in the bogs, while some formed the stumps of trees in position. Since kahikatea is a timber which soon perishes on exposure to the weather, it is evident that the destruction of these forests occurred somewhat recently. This was attributed by the early settlers to the action of fire; but it is difficult to understand how a water-logged swamp could have been thoroughly burnt out, and it is extremely probable that this part of the forest of the plains disappeared largely owing to the killing of the trees by water-logging due either to depression of the land or to the flooding of the land owing to the changing course of the rivers, itself perhaps partly due to depression, of which there is entirely independent evidence." (Speight, 1917.)

It is interesting to note that the long-maintained high water table of the last few years is held to be the cause of the killing of bluegums and pines of considerable age (? 30 years) on Mr. Tallott's farm near Cust.

(2) *Artificial Drainage:* Artificial drainage in the past century of settlement has profoundly altered the aspect of this part of North Canterbury. Not only has the Eyre been diverted into the Waimakariri about five miles west of Clarkville, and many changes made in the lower part of the course of the Waimakariri for the purpose of protecting adjacent land from flood damage, but also many smaller watercourses have been diverted, and several creeks that formerly petered out in swampy patches or disappeared into the porous gravels have been linked with others on the lower plains and eventually led into one of the main rivers. Alterations have been made for drainage, water supply to water races, and water power for flour-mills. Some paddocks have been tile-drained, notably near Clarkville and Rangiora, and where there is still sufficient outfall and the drains are in good condition, the water table is kept by this means sufficiently low for farming. The extent of this change may be appreciated by a comparison of Doyne's map of 1865 (Fig. 5) with maps of the present day.

The form of the water table at present is probably far more irregular than it used to be under natural conditions. In areas adjacent to deep drains (e.g., parts of the Cust Main Drain and its laterals) the land is well drained, with the water table at an adequate depth below the surface. In other parts where drains have become shallow or blocked or have insufficient fall, the reverse is true. A recent example of the beneficial effect of good drainage is provided by the deepening last year by the North Canterbury Catchment Board of Greig's Drain, near Clarkville. The water table in nearby paddocks was lowered about two feet, and land was able to be ploughed where no cultivation had been possible for many years. A further cause of the rapidly changing ground-water conditions, sometimes even in the same paddock, is the fact that the topography of the plains is in detail much more irregular than it appears at first sight. Differences of elevation of a few feet are common in short distances, marking abandoned watercourses and levees, and perhaps differential settling of surface deposits after changes in drainage, either natural or artificial. Where the water table is within a few feet of the surface these differences, though small in amount, may have a profound effect on the nature of the

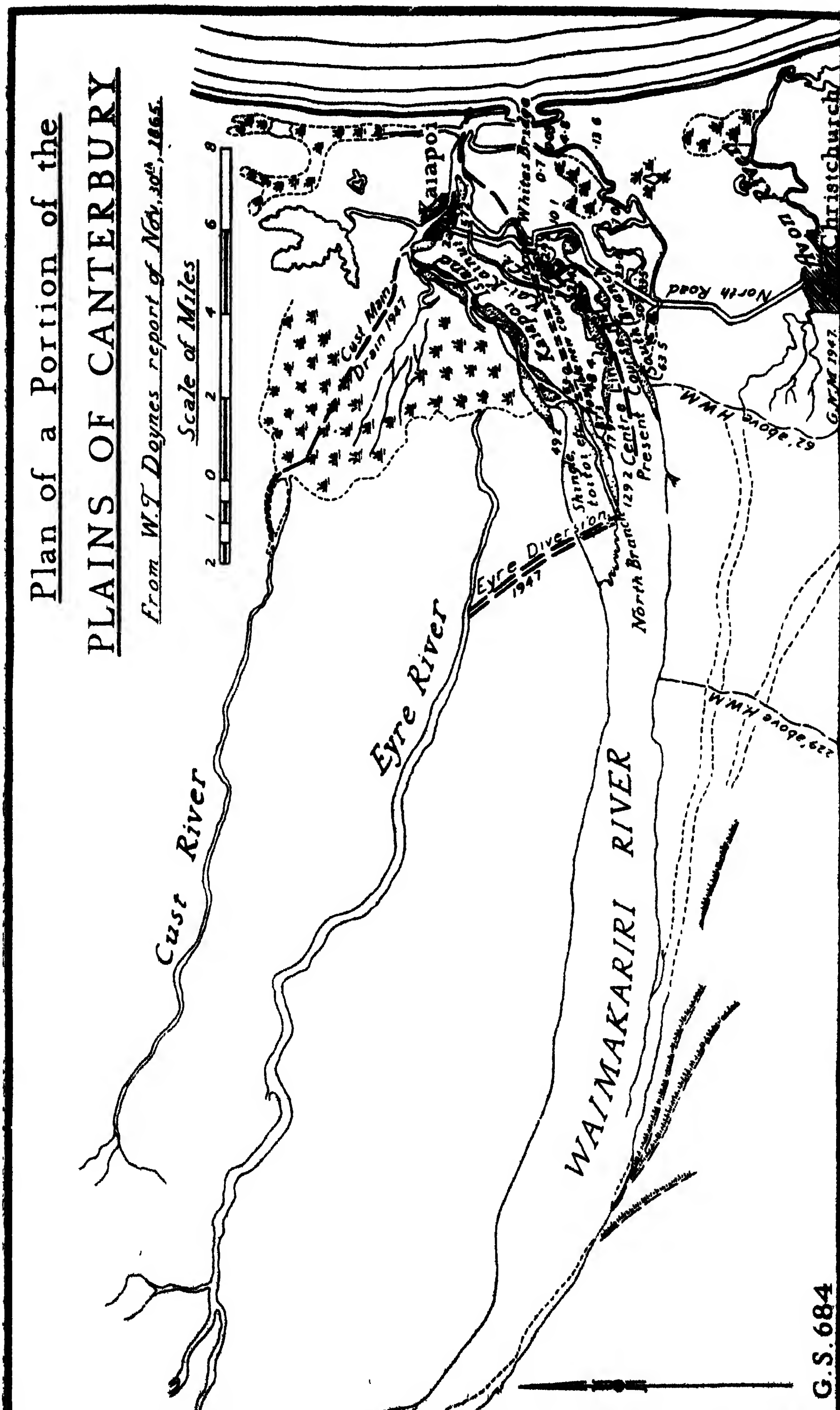
Plan of a Portion of the
PLAINS OF CANTERBURY
From W.T. Doynes report of Nov. 30th, 1865.
Scale of Miles
2 1 0 2 4 6 8
Cust River
Eyre River
Cust Main Drain 1947
Eyre Diversion 1947
WAIMAKARIRI RIVER
North Branch
Present
Centre
South
Kaiapoi
Whites Bridge
North Road
Avon
Christchurch
62 above H.W.M.
229 above H.W.M.
G.K.M. 1947
G.S. 684

FIG. 5

land from an agricultural point of view. No accurate contour map of this part of Canterbury exists, and hence much more work would be entailed in the preparation of a water-table contour map.

(3) *Present Conditions:* The areas at present requiring relief from an excessively high water table may be divided into two types:

(1) The coastal lowlands, lying between the eastern margin of the piedmont alluvial plain proper and the zone of beach ridges and dunes. Here were located the original swamps that were drained early in the history of the settlement of Canterbury. It is obvious that many drains are not now adequate to carry off excess water. Deepening, cleaning, and replacing inadequate culverts should do much to assist in a quicker disposal of the water and a general lowering of the water table. The small fall to the sea will, however, always present a problem in the adequate draining of these areas. Besides the last few years of unprecedented rainfall, a quicker run-off from the upper parts of the plains may have increased both surface- and underground-water troubles in this district. In its native state the land was slightly undulating in topography, and rain-water was held for long periods in pools; native grasses and forest probably retained more water than introduced grasses and crops. The recent increase in the area brought under cultivation, for example, round Oxford, must have disturbed the former conditions—ploughing, for instance, tends to plane out the surface—the amount of water evaporated and transpired has probably been reduced, and the nett result has probably been a quicker and possibly greater run-off, accentuating water troubles in the lower part of the plains.

(2) Areas where springs and seepages occur on the piedmont alluvial plain itself—e.g., on either side of the Eyre River from Horrelville east to the diversion, and south of Cust. Some of these springs may be fairly readily explained as occurring in relatively low places where the water table lies naturally close to the surface. In other places, however, it seems clear that surfacing ground water is under artesian pressure and reaches the surface in localities where there happens to be a porous conduit.

In support of the view that some at least of the springs are artesian may be cited the following facts:—

(a) Flowing artesian springs are known in other areas of North Canterbury, e.g., in Hoon Hay Valley and in Beckenham Park, Christchurch. The flow from the latter springs (about a million gallons a day) is affected by the rate of pumping from the artesian wells at the Christchurch City Council's Main Pumping Station about half a mile away. Most of the wells at this station are about 80 ft. deep.

(b) In the eastern part of the area logs of artesian wells frequently record interbedded clays and tight impervious gravel beds as well as porous and permeable gravel and sand. It is probable that impervious beds extend westward considerable distances and confine ground-water in some places. The nature of the surface deposits—soil and its parent material—greatly influences whether ground water can rise to the surface or not. At Ohoka, for instance, surface clay overlies water-bearing gravel, and when the clay layer is penetrated (e.g., by a post hole) water rises (in periods of high ground water) some distance up the hole or even to the surface. Similar conditions obtain at Flaxton and probably at many other places where fine-grained deposits form the upper layer of the plains. The extreme variability of surface conditions from place to place on the plains

is apparent from a study of the soil maps being prepared by the Soil Bureau, and is also borne out by the experience of farmers and those concerned with the construction of water-races. In some places no trouble was experienced with leakage from races, but in others it was only with great difficulty that the channels were rendered water-tight. Concrete culverts had to be used in places to convey the water across a section (often quite short) of very pervious country.

(c) In many places the surfacing of ground water is not prevented by the digging of ditches several feet deep on the upper (west) side of the seepage or spring.

(d) Sub-artesian water (rising in a pipe above the level of the water-table but not to the surface of the ground) is known at many localities outside the area of artesian flow. The boundary of the artesian-flow area is marked approximately on the map, Fig. 1.

(e) Near Rangiora, on Mr. Leech's farm, it is claimed that a seepage may be started merely by pulling out a willow stump. In an area of only 20 acres Mr. Leech estimates that there are about 200 separate springs, many of which are on relatively high ground. In this district heavy clay soil overlies gravel. Artesian water rises about three feet above the surface from a depth of 25 to 30 ft.

Frequently the entire blame for the exceptional ground-water conditions of recent years has been placed on the fact that the Eyre and Waimakariri are building up their beds by deposits of gravel, thus raising their water levels and hence the water table in adjacent land. Though this may be a contributory factor, careful surveys show that it can only be a minor one. From cross-sectional surveys made by the Waimakariri River Trust's officers, it appears that the Eyre has aggraded its bed over an average channel width of 400 yds. by about one foot in 23 years. Measurements made at the Highway bridge show that the waterway of the Waimakariri has been reduced by less than $1\frac{3}{4}$ per cent. in the last 15 years. In October, 1931, the waterway was 22,500 square feet; recent surveys show it to be now 390 square feet less. The average rise in the level of the bed is thus 4.2 in. in 15 years, or about a-quarter of an inch a year.

Unlike parts of Mid- and South Canterbury, where irrigation is practised, North Canterbury cannot be affected to any extent by seepage of irrigation water, since the only water added to the area is the small amount supplied in stock-water races. During construction some trouble was experienced with leakage from these races, but this has apparently been overcome, and all races are now considered to be effectively sealed. There is certainly no evidence of leakage at present, even where races run within a few feet of gravel pits or drains. Water races can affect drainage problems only if, during heavy rain, the water is not turned off at the intake (as is said to happen occasionally). Accretion of run-off further down the race may then cause flooding, and also prevent the races functioning as drains, as apparently some at least are expected to do.

In summary, it may be stated that the present unsatisfactory drainage situation in the area is the result of a combination of factors, among which, roughly in order of importance, are:—

(1) The excessive rainfall of the past three years, perhaps aggravated by the fact that of the last 11 years, 7 have been years of more than average rainfall (see Fig. 2).

(2) The gradually deteriorating condition of existing drains, many of which, through lack of proper attention, have silted up, become choked by the growth of willows and aquatic weeds, trampled in by stock, etc.

(3) Changes concomitant with the advance of settlement and extension of the area under cultivation, such as quicker run-off from the foothills and upper plains, less water lost by evaporation and transpiration as the areas of surface pondage and forest and other natural vegetation have been reduced.

(4) Aggradation of river beds, raising the water level in the rivers and hence affecting the water table in nearby land where the water table and river water are inter-related.

PROPOSED DRAINAGE SCHEME

The proposed Eyre–Cust Drainage and Flood Control Scheme (recently renamed the "Oxford-to-the-Sea Scheme") is a comprehensive scheme designed by the North Canterbury Catchment Board to improve the drainage of surface water from the area, to control flooding of the many watercourses, and also "to serve in assisting to cut off and discharge so much of the undercurrent [ground water] as may be possible" (report of Mr. H. W. Harris, engineer to the Catchment Board).

From the points of view of drainage and flood control the scheme seems to be necessary and adequate. At present, during floods in the Eyre and Cust, many of the minor drains do not function because the water levels in the rivers are higher than those in the drains intended to discharge into them, causing the backing up of water in the drains and accentuating water-logging of the soil. With the diversion of the Cust River into the Ashley and the Eyre into the Waimakariri as proposed, the channels of the Cust and Eyre would become available for the water from the lateral drains, enabling them to function properly at all times.

With the limited amount of information available as to the ground-water conditions in the area, it is difficult to predict just what will be the effect of the scheme on the water table. Mr. Harris in his report presenting the scheme, states that:—

"Undercurrent is dealt with in the system of cross drainage. In this regard an examination of the district discloses that most of this water comes from certain definite localities and that the intervening parts contribute relatively little but suffer severely from the surfacing of such undercurrent. . . . For this reason as many cross drains as appear reasonable are suggested in order to prevent aggregation of water in the lower parts of the district and also to serve in assisting to cut off and discharge so much of the undercurrent as may be possible."

Cross drains, where constructed in pervious material should definitely help to lower the water table, provided they are deep enough. In places, however, it is probable that the ground water that comes to the surface is artesian; such springs may continue to flow in wet seasons. The drains proposed would, however, carry off this spring water before it could do much damage by flooding over the country as at present.

Since a great part of the ground water appears to be supplied not so much by rivers as by rainfall over a wide area of the plains, it is probable that the proposed diversions of the Cust and Eyre will have little effect on the average level of the water table throughout the area. Even without the addition of water through the lateral drains, it is probable that

the Cust and Eyre will flow at times below the points of diversion. Such effect as the diversions may have, however, can only be beneficial, since in the opinion of soil and agricultural experts, it is practically impossible to overdrain soils, especially those of a heavy (silty or clayey) nature such as are found in most of the areas in this district that require further drainage. It is possible that some small areas of light land, as, for example, that near East Eyreton, will be affected adversely by a lowering of the water table. It is said that record yields of wheat and prolific growth of pasture have been obtained in the last few years in this last-mentioned locality without any associated ill-effects. It is possible, nevertheless, that these desirable results are connected mainly with the recent high rainfalls (especially during the growing seasons) rather than with the position of the water table.

The great advantage of the scheme apart from the flood-control and surface-drainage aspects will, without doubt, be the provision of outlets, available at all times to those farmers desirous of constructing internal drains on their properties. In many places at present, for reasons given above, such outlets do not exist, especially after heavy rain.

It is concluded that the "Oxford-to-the-Sea" Drainage and Flood Control Scheme, as proposed by the North Canterbury Catchment Board, will have a beneficial effect on ground-water conditions in the area and enable successful field drainage of wet areas to be undertaken.

ACKNOWLEDGMENTS

In the preparation of this report, much assistance was received, not only from the papers cited in the list of references (and others), but also from many residents of the district and officers of the following local bodies: North Canterbury Catchment Board, Rangiora Borough Council, and Waimakariri-Ashley Water Supply Board.

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POSTSCRIPT (March, 1950)

At the time the scheme was first proposed (January, 1946) and for somewhat more than a year afterwards, the district was experiencing serious flooding and water-logging, and was obviously in need of improved drainage if agricultural productivity was to be restored to its former level.

As shown in the paper, the high ground water levels were in great part due to more than average rainfall during successive years. Rainfall during 1947, however, was slightly below average, and during 1948 and 1949 considerably below. The water table throughout the district fell appreciably, and for some time now there has been no general need for improved drainage. Some wells have actually gone dry, and a shortage of water has developed during the last two summers. For some time the Catchment Board remained convinced that it was still desirable to carry out the scheme as originally proposed; later some minor modifications were incorporated; but the opposition became more and more vocal. Two petitions signed by a large number of ratepayers were presented to Parliament. The Committee that heard these petitions called evidence from the Geological Survey. This evidence emphasized two points that had received but scant treatment in the above report:—(1) ground water in the belt of country along both sides of the Eyre River is partly supplied by leakage from the river, as shown by the dependence of watertable levels in this area on the flow of the Eyre River; and (2) the recent series of wet years was quite exceptional in the history of white settlement in Canterbury, the average annual rainfall over the ten years 1938–1947 being higher than that of any preceding similar period since rainfall records were begun in Christchurch in 1864.

As stated in the preceding article, the work on which it is based was done in October and November, 1946, and February, 1947. The article was written in March, 1947. Since then objections to the Catchment Board's proposed drainage scheme were advanced by a number of farmers in the district, and after protracted negotiations the Board finally decided, in December, 1949, to suspend the scheme indefinitely.

AN AUTOMATIC RECORDING POLAROGRAPH

By T. J. SPROTT, Auckland University College, Auckland

(*Received for publication, 1 April, 1948*).

Summary

A recording polarograph is described which does not involve photography, but gives a trace of the current-voltage curve in ink on ordinary graph paper.

INTRODUCTION

THE basic measurements of the polarograph, an instrument devised originally by Heyrovsky and Shikata (1), are those of the continuously varying voltage applied to a pair of mercury electrodes, one of which is of the dropping type, and of the current flowing under this voltage through a solution which completes the circuit between the electrodes. Under proper conditions the curve of current *versus* applied voltage is determined by the oxidation-reduction properties of the solute, and consequently such curves can be used for the qualitative detection of the constituents of the solution and also for quantitative analysis of the solution. In recent years the instrument has received wide application in both analytical and industrial chemistry; the biological assay of 17-keto steroids by Barnett, Henly and Morris (2), the procedure devised by Lingane (3) for determining tin, lead, nickel and zinc in copper-base alloys, and the polarographic determination of azides (4), may be quoted to illustrate the variety of problems open to attack by this method. It is possible to make current measurements in an apparatus in which the voltage increase is controlled manually; the procedure is, however, time-consuming and tedious. On the other hand the automatic recording machines at present available, in which the current is measured by allowing the light reflected from a galvanometer mirror to record on a photographic drum, are relatively expensive to operate. This paper will describe the construction of an automatic polarograph from normal laboratory equipment, which has been found to give very satisfactory service.

APPARATUS

Polarographic Cell

This consisted of a 3 ml. glass vessel with a pool of mercury at the bottom to act as one electrode. The other was of the flowing type, mercury being run through a 10 cm. length of capillary tubing to produce drops about 0.5 mm. in diameter with a drop time of 2 seconds.

The Current Recorder

The set up of the apparatus is illustrated. For the current recorder two photoelectric tubes, Type CE1, were mounted on a large ½ in. Whitworth nut through which passed a specially trued shaft of Tobin bronze threaded correspondingly. This shaft, 17 in. in length, was mounted between two brass bearings screwed into the ends of the supporting member, a strip of 3 in. x ½ in. copper bent up 4 in. at the ends. The whole was lined up accurately, the end play of the shaft being about 0.005 in. with negligible slackness in the shaft bearings.

This shaft was geared to a small commutator type motor mounted at one end of the supporting member. When the shaft was rotated by the motor, the nut carrying the photoelectric tubes moved, carrying with it a fountain pen which slid along a rigid stay on the supporting member. This also prevented the nut from rotating.

Associated with this mechanical contrivance was an electronic circuit which took the impulses from the photo-tubes and translated them into rotations of the threaded shaft, such that if light fell on one tube the nut supporting the tubes moved in one direction until the beam passed between the tubes and vice versa. Thus the tubes continually sought to centre themselves on the light beam. This was achieved with the circuit shown (Fig. 1).

The relays shown were of telephone origin and were slugged so as to give a quick-make slow-break characteristic. Care was taken to ensure that they had the same operating current. They were mounted, together with their operating tubes, Thyratrons Type 884, on a small chassis.

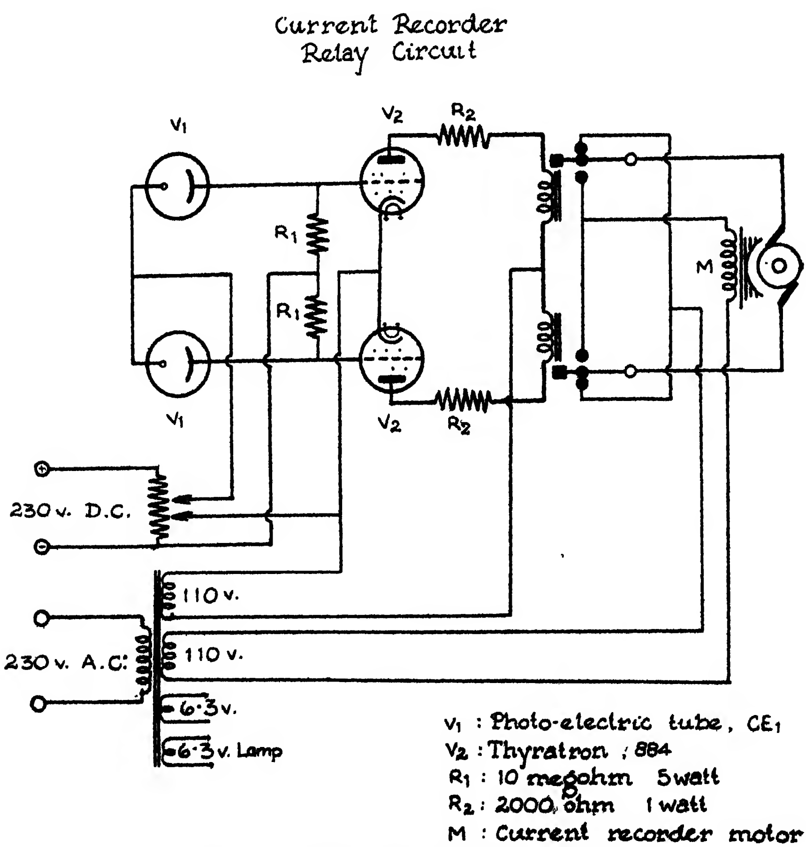

FIG. 1.—Current recorder relay circuit.

OPERATION

As the intensity of light falling on the cathode of one of the photo-tubes increased, the anode current through this tube rose so that a potential was developed across the 10 Meg-Ohm. resistance forming the anode load of that tube. This potential overcame the bias applied to the

corresponding thyratron. At a certain stage, which could be adjusted the bias became of such a value that anode current started to flow in the thyratron, and the enclosed gas ionized instantly since the ionizing potential was exceeded considerably. The grid immediately lost control and so a comparatively large current, 40-50 milliamperes, flowed, sufficient to close the relay firmly and so complete the armature circuit of the motor, causing it to rotate. As the phototube moved away from the light it was necessary that the motor should stop. This was easily arranged by supplying the plates of the thyratrons with A.C. so that the plate current stopped and the grid regained control for an instant, 50 times a second. The slugging of the relay was sufficient to keep it closed without any chattering, but it opened instantly when the grid of the thyratron regained proper control. If light fell on the other photo tube the direction of the current through the armature was reversed so that the carriage moved the other way. Since both the bias and photo tube anode voltage were independently variable it was very flexible and this gave an automatic means of averaging the current indicated by the galvanometer.

As already indicated the potentiometer drum and paper movement were similar to those in most recording polarographs.

It was desired to draw the paper at a constant rate past the current recorder and at the same time increase the voltage applied to the polarographic cell. For this purpose it was necessary that the paper pulling mechanism should be geared directly to the potential divider supplying the cell so that distances along the paper should indicate the voltage.

It was also necessary that the change in voltage and the movement of the paper should be very slow and it was anticipated that the voltage should rise from zero to 2 volts in about 15 minutes while the paper should move about 12 in. Two sets of gears were available, one having a 12:1 and the other 6.5:1 ratio. A pair of typewriter rollers was to be used to draw the paper through, and a wire-wound potential divider with a sliding contact varied the voltage.

The rollers drew through 13 in. of paper in three revolutions so that the divider drum was made to have 3 x 6.5 = 19.5 turns of wire on it. The drum was turned from a 4 in. diameter rod of ebonite 6 in. long in which a square thread 3.5 turns per inch was cut. Two strands of No. 20 gauge Constantan wire were laid along the bottom of the thread and at the ends were passed radially to the centre of the helix inside the ebonite.

An A.C. synchronous motor was used to drive this arrangement and a series of reduction gears employed such that the paper speed was about 2 cm. per minute.

The sliding contact was a brass strip 8 in. x ½ in. x ⅛ in. freely pivoted at one end and weighted so that it rested firmly on the potentiometer wire. It was found that if the sharply pointed contact was placed in the space between the two wires which were liberally coated with vaseline, a reliable connection was made and the pointer followed the wire as the drum rotated.

In order to make each square on the graph paper correspond to some fraction of a volt, it was simply necessary to measure the distance which the paper travelled while the pointer moved from one end of the drum to the other, and then adjust the voltage across the drum accordingly.

In one experiment 15.3 in. of paper were pulled through and therefore the voltage was adjusted to 1.53 volts so that each inch corresponded to 0.1 volt.

Alternatively it was possible when using paper ruled in cm. to make 1 cm. correspond to 0.1 volt or 0.05 volt, etc., as desired.

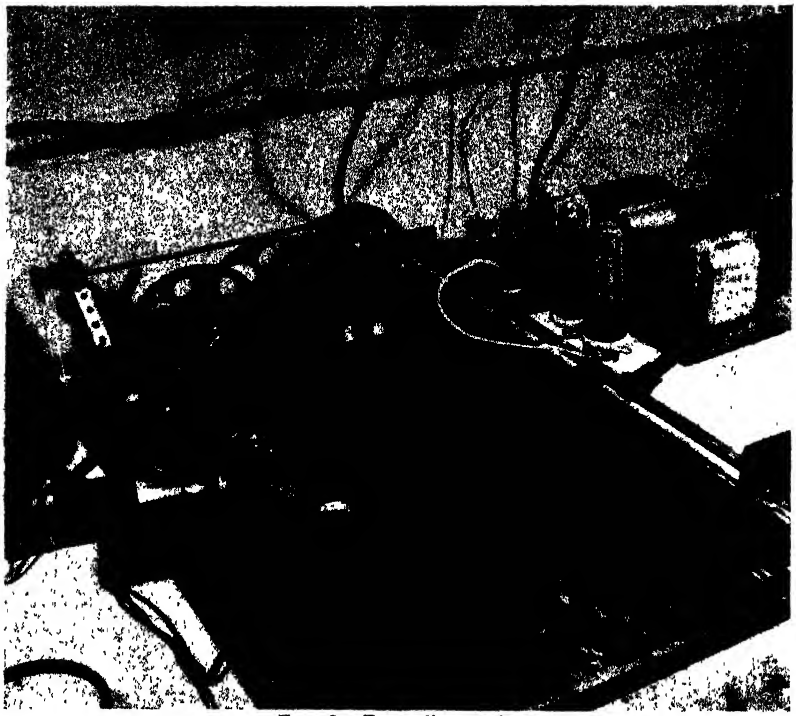

FIG. 2.—Recording unit.

ADJUSTMENTS

The whole apparatus was set up as shown in the photograph (Fig. 2), the current and voltage recorders being screwed to a base board. It was from the windows which would render them unstable. The galvanometer was mounted on two heavy blocks of copper to absorb vibrations from the bench.

A galvanometer projector, containing a 6-volt, 25-watt lamp supplied from a 6.3 volt winding on a transformer, was mounted on the front left of the baseboard and an additional converging lens placed between the projector and the mirror to focus the image on the photo tube cathodes. When properly focussed a well-defined image of the filament could be thrown on the cathodes, of sufficient size to fill them completely. Several lamps were tried and the one selected had a short straight-coiled filament which gave a very intense light, ideal for the purpose.

The graph paper was then inserted between the rollers and placed so that the rulings were parallel with the supporting member stay. The carriage was moved, by depressing the correct relay, to the front edge of the paper, and an ordinary fountain pen clipped into the pen carrier, which was loaded so that the nib rested lightly on the paper, immediately above the writing roller.

The transformer supplying the lamp and heater current was turned on and the galvanometer mirror rotated until the beam passed between the photo tubes. The apparatus was then in readiness for an experiment. A typical polarogram is shown in Fig. 3.

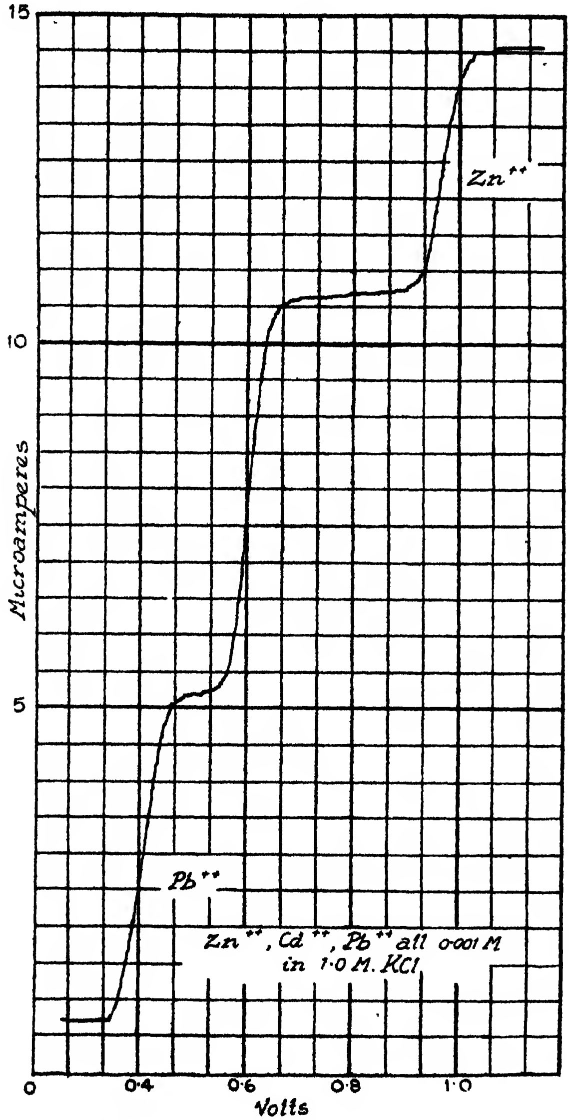

FIG. 3.—Polarogram of lead, zinc, and cadmium ions, each 0.001 molar. Supporting electrolyte molar potassium chloride, drop time 2.0 seconds. Actual size, 13 in.

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A BACTERIAL DISEASE OF *Dysoxylum spectabile* CAUSED BY THE PATHOGEN *Pseudomonas dysoxyli* n. sp.*

By P. B. HUTCHINSON, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(*Received for publication, 24th February, 1948*)

Summary

A disease affecting approximately 99 per cent. of mature *Dysoxylum spectabile* is described The host plant occurs in coastal areas of the North Island and the extreme north-eastern portion of the South Island, the disease being present throughout. Although the proportion of young trees infected is less than that of mature trees, both are shown to be equally susceptible.

The symptoms are (a) greasy, translucent leaf lesions, (b) "shot-holes" in the leaf tissue, (c) greasy lesions in the leaf axils. Symptoms are present throughout the year but there is less infection during winter Transmission of the disease is effected by contact with diseased tissue and by rain-splash.

The causal agent is shown to be a new, probably endemic bacterial pathogen for which the name *Pseudomonas dysoxyli* n. sp. is proposed Its morphological, physiological and cultural characteristics are described.

INTRODUCTION

ALTHOUGH fungous parasites are frequently recorded on the native flora, the occurrence of a bacterial pathogen is unique. This paper records a bacterial disease of the endemic forest tree *Dysoxylum spectabile.* This species is the only member of the genus *Dysoxylum* occurring in New Zealand and *Dysoxylum* is the only indigenous genus of the *Meliaceae.* The present host species therefore shows a high degree of endemism.

Saccardo (1899) recorded the fungus *Mebola MacAlpini* Sacc. et Syd. on the leaves and petioles of Australian *Dysoxylum* species and subsequently (1906) recorded *Rhoma dysoxyli P.* Henn. on the same host. The various symptoms described in these reports are quite distinct from those under consideration in the present paper. There is no record in the available literature of bacterial infection of any members of the *Meliaceae.*

SYMPTOMS OF THE DISEASE

The symptoms are easily recognised macroscopically on both leaves and stems. Lesions have not been observed either on green or on ripe fruits.

LEAF INFECTION

Symptoms are dependent on environmental conditions and the period during which the leaf has been infected. (See *Pathogenicity Studies*). However, they are usually evident in three, more or less separate, phases.

Phase (i) "Grease-spot" condition: circular, greasy translucent areas sharply differentiated from the uninfected portion of the leaf and visible both dorsally and ventrally. The zones may be up to 10 mm. in diameter.

Phase (ii) "Corky" condition: hard, greyish-brown to black, dry corky areas with a dead appearances.

* This paper is abstracted from a thesis presented as part of requirements for M.Sc. Degree.

Phase (iii) "Shot-holed" condition: this follows when the dry, corky regions of Phase (ii) fall from the leaf, leaving areas entirely missing. These areas range in size from about 4 mm. in diameter to almost the whole surface of the leaf. The periphery of the abcised area shows a corky condition.

FIG. 1.—Leaf Showing Various Infection Phases.
'A'—Early "Grease-spot" phase
'B'—Late "Grease-spot" phase
'C'—Abcission-ring commencing
'D'—Abcission-ring almost complete
'E'—Completed "Shot-hole"

(Photo. by P. B. Hutchinson)

These phases are not absolute; each grades into the next as infection develops. Phase (i) is characteristic of young lesions, occurring about six days after infection. At this stage the translucent portion of the infected leaf still appears to be living and bacterial cultures are easily isolated from any part of the infected area. Although this "grease-spot" condition is invariably present in the initial stages of infection, the symptoms of the later stages are less regular.

As the lesion ages the translucent area increases in diameter and the central portion becomes brown and brittle, but still yields viable bacteria. This brown portion in turn enlarges and encroaches on the translucent area. At this stage the first indications of "shot-hole" formation become evident. An incomplete abcission-ring forms, separating the lesion from the uninfected tissue surrounding it. Subsequently, depending on the speed of formation of the abcission-ring, the infected portion may become dry and brittle in the centre only or may extend over the whole area. Because of shrinkage of the dry tissue and completion of the rupture, the infected area falls from the leaf leaving the typical "shot-hole".

The characteristic circular form of the lesions is modified when infection is centered at the mid-rib of the leaf. In this case longitudinal spread is more marked; usually, the distal end of the lesion has a greasy appearance and the original seat of infection near the base of the leaf is excised. In some cases the mid-rib itself is severed.

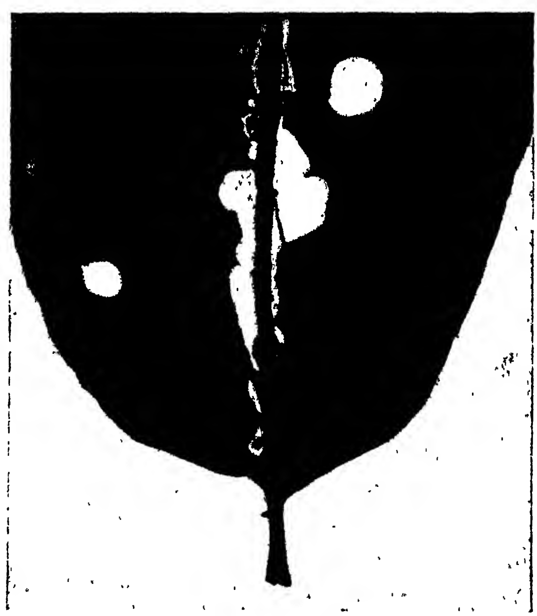

FIG. 2.—Mid-rib Infection.
The older portions of the lesion have been excised but infection is still progressing distally.

(Photo. by P. B. Hutchinson)

STEM AND PETIOLE INFECTION

Lesions may occur on the smaller branches and leaf petioles. They are most commonly found in the axils of the leaf petioles or the leaflet stalks. They are oval in shape, often attaining dimensions of 50 mm. in length by 6 mm. in width.

FIG. 3.—Petiole Infection.
Petiloe infection has caused death of leaf on left

(Photo. by P. B. Hutchinson)

Typical lesions show three distinct zones : a central zone about 2 mm. wide, a narrow black band, and an outer zone with a "water-soaked" appearance. The central area is grey to brown in colour and appears dead, but the outermost zone, although distinct where it is adjacent to the black band, merges into normal green tissue towards the edge of the lesion.

DISTRIBUTION AND INCIDENCE

In a survey of more than a thousand trees covering samples from practically the whole of the host range from North Auckland to Marlborough, bacterial infection was found throughout.

Of the mature trees* investigated, over 99 per cent. showed infection symptoms. In the case of younger trees, the proportion of those diseased dropped to approximately 10 per cent.† The Table shows percentages of infected trees from a sample district.

* For the purpose of the survey, a mature tree was defined as one which possessed at least twelve compound leaves. Such a tree was usually five feet or more in height.

† However, artificial inoculation has shown that young trees are as susceptible to infection as are mature trees. See *Discussion on Methods of Transmission* for possible explanation of the difference between the proportions of the young and the mature groups infected naturally in the field.

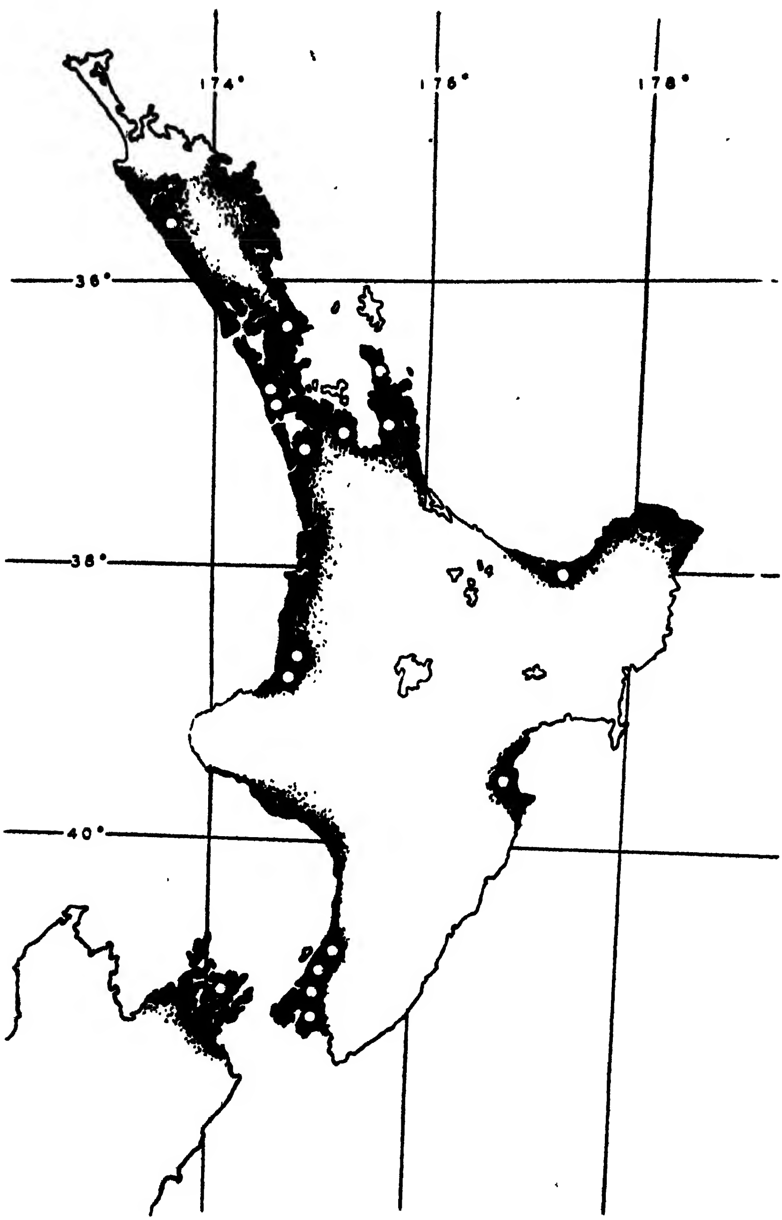

FIG. 4. - Distribution of the Bacterial Disease of *Dysoxylum spectabile*. The stippled areas represent the approximate distribution of the host plant. The circles indicate localities from which isolations of the bacterial pathogen were made.

INFECTION DATA FROM *D. spectabile* IN THE RUAHINE—COOK AND SOUNDS—NELSON BOTANICAL DISTRICTS

Locality.	Maturity.	No. of Trees Investigated.	Total Percentage Infected.	Percentage with Recent Infection.
Marlborough	Adult Young	30 87	100 16	66 16
York Bay, Wellington	Adult Young	11 118	91* 6	73 2
Paekakariki	Adult No young trees; all undergrowth destroyed by sheep.	250	100	71

* This percentage is explained by the presence of one disease-free tree.

Within the distribution area of the host, climatic factors vary considerably. Nevertheless, it is evident that the range of conditions tolerated by the pathogen is at least as great as that tolerated by the host.

CAUSAL AGENT

Infected portions from sample trees were collected throughout the distribution area and subjected to microscopic and cultural investigation.

Microscopically, symptoms of infection were constant. An abundance of rod-shaped bacteria was always evident in the leaf mesophyll and excessive gum formation in infected host tissue was prevalent.

In cultural studies there was marked uniformity in the grey colour of the colonies apparent on the isolation plates. Although colour was uniform, the form of the colonies was exceptionally variable, ranging from micro-colonies to thick films. These were later shown to be different growth-forms of the same organism.

Ninety-eight pure cultures were obtained from specimens of diseased trees representative of most of the distribution area.

Young host plants were inoculated with each of these pure cultures under controlled conditions in the glasshouse. Those plants that had been inoculated with the grey culture developed symptoms identical with those occurring naturally, and on re-isolation from typical lesions the grey colony form was again readily obtained. Plants inoculated with organisms from colonies other than the grey type showed no infection symptoms.

DESCRIPTION OF PATHOGEN

MORPHOLOGY

The bacteria normally occur in pairs, although single organisms are occasionally present. They have the form of short rods with rounded ends. Single rods vary in size from 0.6μ by 0.4μ to 1.0μ by 0.6μ, with an average size of 0.8μ by 0.5μ. They are gram-negative (Hucker stain). The rods are motile, usually possessing a single polar flagellum but occasionally two are present (Leifson stain).

CULTURAL CHARACTERISTICS*

Beef-Peptone-Agar plate:

Colony form is variable. Circular forms range from punctiform to convex colonies up to 8 mm. in diameter; spreading growth also occurs—this varies from diffuse films to thick sheets with dense edges covering much of the plate. The colonies are of a grey colour and are translucent. The surface is smooth and edges are entire to undulate. The medium is stained brown after one week.

Beef-Peptone-Agar stroke:

Growth is abundant, filiform, convex, glistening, smooth, grey in colour and translucent. It is of a butyrous consistency and is odourless. The medium is stained brown after one week.

Beef-Peptone-Agar stab:

Scant filiform stab growth; surface growth moderate, flat, smooth, glistening. The medium is browned at the top and along the line of the stab after one week.

Gelatin stab:

Slight filiform stab growth. Medium stained brown at top. No liquifaction up to 30 days.

Nutrient broth:

Dense flocculent pellicle at surface. Strong clouding after two to three days. No odour. Abundant flocculent sediment.

Purple milk:

No change up to four days. After 12 days half an inch of amber whey present at the top with one inch of flocculent pink precipitate at the base.

Potato slice:

Abundant buff-coloured growth after seven days. Moist, glistening, smooth. Potato stained brown.

PHYSIOLOGY

Fermentation of Carobhydrates.

No gas was formed in stab cultures of media containing the following carbohydrates:—

Arabinose, rhamnose, glucose, fructose, galactose, lactose, sucrose, maltose, raffinose, melizitose, starch, inulin, dextrin, glycerol, mannitol, salicin.

Reaction on Carbohydrates.

No acid was produced in the basal synthetic medium. Acid was produced within three weeks on media containing the following carbohydrates:—

Glucose, fructose, lactose, sucrose, raffinose, and mannitol.

No acid production was evident within the same period in the basal synthetic medium plus the following carbohydrates:—

Arabinose, maltose, melizitose, starch, inulin, dextrin, glycerol, or salicin.

The type of carbohydrate available has considerable influence on the growth of the colonies, the best growth occurring with fructose and maltose.

Indol Production.

The Gore modification of the Ehrlich-Bohme test showed no indol production on tryptophane broth after seven days.

* "Difco" media used throughout.

Hydrogen Sulphide Production.

The lead acetate test-strip method revealed no hydrogen sulphide production on a medium containing available sulphur.

Diastatic Action.

On a medium containing soluble starch, treatment with Lugol's solution revealed strong hydrolysis after four days.

Methyl Red and Voges-Proskauer Reaction.

Negative results.

Nitrate Reduction.

The sulphanilic-acid —*a*— naphthylamine reagents showed no production of nitrates either in broth or on solid medium.

Temperature Relations.

The optimum temperature for growth is 25°c. although cultures can be maintained at a temperature as low as 4°c. or as high as 36°c.; however, growth at these extremes is poor.

Temperature also influences the longevity of cultures. Broth cultures stored at a range of temperatures from 4°c. to 36°c. were all alive at the end of 18 days but above 36°c. viability decreased rapidly. Though no measurable increase in the number of organisms occurred up to 18 days at 4°c., cultures held for two months at this temperature were still viable and still pathogenic. Cultures held for two months at 36°c. however, did not yield viable isolates.

CLASSIFICATION OF THE PATHOGEN

The fact that the organism is a gram-negative, non spore forming plant pathogen, motile by a polar flagellum and producing a water soluble pigment places it within the genus *Pseudomonas* Migula 1894.

Bergey *et al.* (1939) divide the family *Pseudomonadaceae* into several genera and place the plant pathogens in the genus *Phytomonas*. Pathogenicity, as a character for limiting a genus, is questioned by Burkholder (1930) and further, Elliot (1937) has suppressed the name *Phytomonas* on the grounds that it is a homonym.

W. J. Dowson (1939) has redefined the genus *Pseudomonas* and has excluded from it organisms producing acid in lactose, maltose and salicin. According to Dowson, those organisms producing acid from any of these carbohydrates must be accommodated within the genus *Bacterium* (organisms motile exclusively by peritriciate flagella), or within his newly erected genus *Xanthomonas* (which is reserved for "organisms yellow in the mass on nutrient agar and on potato").

The organism under consideration produces acid from lactose (but not from maltose or salicin), possesses a single polar flagellum (rarely two), is grey in the mass on nutrient agar and buff-coloured on potato. It thus cannot be placed within any of the genera defined by Dowson.

However, it is proposed that, rather than erect a new monotypic genus, the organism be included in the genus *Pseudomonas*, notwithstanding its suggested restriction.

Thus the name *Pseudomonas dysoxyli* n. sp. is proposed for the organism.

PATHOGENICITY STUDIES

Field surveys, by establishing the fact that the disease is practically universal, suggest that the pathogen tolerates a wide range of conditions. In order to determine these conditions, experiments were initiated under natural environment and under controlled environment in the glasshouse. It was possible to produce infection of leaves and stems by the application of inoculum to scalpel incisions or carborundum abrasions, by inoculation with syringe and also by application of inoculum by spraying. It appears that infection is facilitated by prior damage although it may occur in the absence of such damage.

Effect of Inoculation under Controlled Conditions.

The illustrations follow the progress of infection in the same terminal leaflets.

FIG. 5.—18 Days After Inoculation. "Grease-spots" evident but still localized to the points of inoculation.

FIG 6. -28 Days After Inoculation. "Corky" condition becoming apparent and "shot-hole" phase commencing.

FIG. 7.- 34 Days After Inoculation. One lesion has progressed to the "shot-hole" phase.

FIG. 8.- 38 Days After Inoculation. Severe infection has induced general chlorosis.

(Photos. by P. B. Hutchinson)

AGE OF TREES INFECTED

A range of host plants varying from seedlings 3 in. in height to mature trees of 40 ft. were inoculated under forest conditions. Infection resulted in all cases. There was no gradation in the period required for infection to become evident nor did the age of the host plant appear to govern subsequent development of lesions.

AGE OF LEAVES INFECTED

Infection was easily demonstrated in leaflets ranging in length from less than ¼ in. to leaflets over 8 in. long which had been labelled more than a year previously. The age of infected leaves, however, appears to affect subsequent development of lesions. On older leaves, the " grease-spot " phase tends to be shortened, with the result that " shot-hole " formation occurs earlier. Thus lesions are usually smaller than those on a younger leaf under the same conditions. Large leaves, when recently infected commonly have many small " shot-holes " of 1 to 2 mm. in diameter, whereas younger leaves show larger " grease-spots " and " shot-holes ".

SEASONAL EFFECTS

Casual observations indicate that, although symptoms of the disease are present throughout the year, maximum development of lesions occurs during the summer months. To give this generalization a statistical basis and in order to find if correlation with climatic or biotic factors was possible, inoculations were made and lesion areas measured throughout the year.

Every 20 days, 40 inoculations of leaves of uniform-size with a day-old culture were made. At periods of 20 days and 40 days after inoculation, the area of each lesion produced was measured.

The recordings and measurements are shown graphically below. The humidity (i.e. relative humidity) curve was obtained by averaging readings over ten day intervals ; the temperature curve was similarly obtained and refers to the minimum temperature. The lower limit of the shaded region represents the average area of the 40 lesions 20 days after inoculation, and the upper limit, the average area after 40 days. The shaded region denotes the average increment in lesion area over the intervening twenty-day period.

DISCUSSION OF RESULTS

It was possible to achieve infection throughout the year but inoculation at different seasons produced lesions varying considerably in area within the twenty-day or the forty-day period.

In the period from October until early March, viz. during summer, the lesions produced were of much greater area than lesions produced during the rest of the year. During this summer period, it will be noted that there was a marked correlation between humidity and the areas at 40 days, and that the increment, i.e. the difference between the areas at 20 days and 40 days, was also associated with humidity, reaching a maximum with the maximum humidity and falling rapidly when minimum humidity was attained in March.

From April to September, the autumn and winter seasons, there was no such correlation between humidity and lesion areas, the humidity being maintained at a high level (about 90 per cent.) and the average lesion sizes at areas less than 10 sq. mm. During this period however, the minimum temperature had fallen to its winter level of between 7°c. and 10°c. Although laboratory tests showed the organism to be viable at these temperatures, growth of the organism within this range was poor.

It therefore appears that the minimum temperature is a limiting factor in lesion development, small lesions resulting from inoculations in the period from late May to September, when minimum temperatures seldom exceed 10°c. During the summer months lesion development appeared to be governed by humidity.

An additional factor appeared to be controlling development in the period from late October to early November, when, although humidity and temperature were both low, moderately large lesion areas were recorded. Conversely, in the April and early-May period lesion area was small, notwithstanding relatively high humidity and temperature. It is possible that a single factor could account for the apparent discrepancies in correlation for both of these periods, viz, the state of the inoculated leaves. It may be postulated that the young spring growth in the October period favours the development of lesions although conditions are well below optimum, and that the maturing and hardening of leaves about April commences a period of small lesion development despite favourable climatic conditions. (Since these data are drawn from measurements taken in a single year it is not desirable that definite conclusions should be drawn and the postulates above are tentative only.)

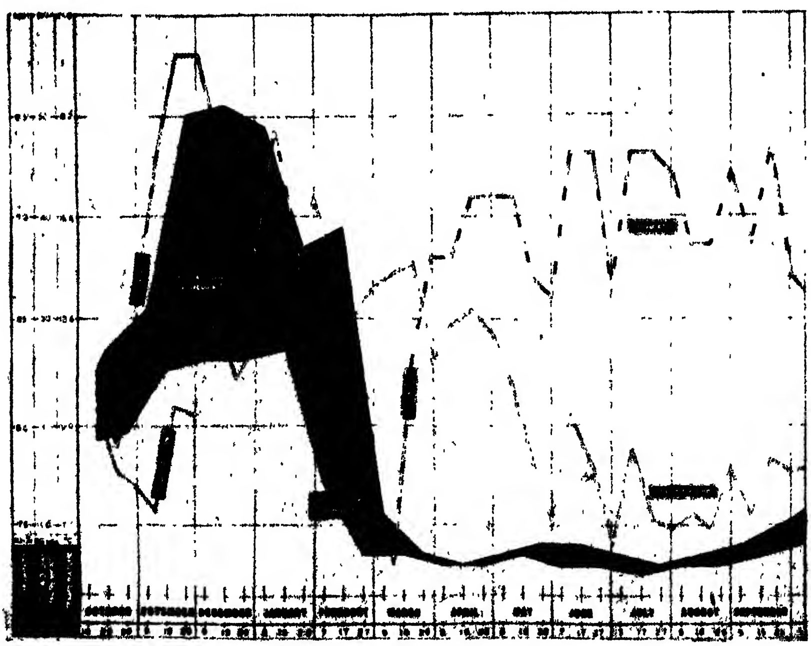

FIG. 9.—Effect of Season on Size of Lesions.

(Photo. by P. B. Hutchinson)

TRANSMISSION OF THE DISEASE

From the widespread occurrence of the disease, it is apparent that the pathogen is readily transmitted. A series of experiments was conducted to determine methods by which transmission may be effected.

CONTACT BETWEEN INFECTED AND CLEAN LEAVES

Under natural conditions in the forest, portions of diseased leaves fallen from " shot-holes ", or leaves that have become detached due to petiole infection, are commonly found adhering to clean leaves. The sticky nature of the lesions under moist conditions facilitates adhesion.

Experiments were conducted to determine whether this contact between infected and disease-free plants provided a means of transmission of the pathogen. Diseased leaves both attached to the plant and removed from it, were placed in contact with uninfected leaves. Ventral and dorsal leaf surfaces were paired in all possible combinations. A similar arrangement was repeated using disease-free leaves that had been deliberately damaged.

Within 14 days those leaves disease-free at the time of pairing showed symptoms of infection. In the case of the damaged leaves infection occurred within seven days.

Fragments of diseased leaves and portions of tissue excised during " shot-hole " formation are commonly found on the forest floor. These, even when they appear to have been separated from the parent plant for long periods, invariably yield viable isolates of the pathogen when plated. It thus appears that the organism will remain viable in such tissue for more or less extended periods, and that the raw humus must be regarded as a potential source of infection.

TRANSMISSION BY WATER-DROPLETS

Water droplets which had been in contact with one of a range of leaves each showing a different phase of infection, were permitted to drop on to either the ventral or the dorsal surfaces of disease-free leaves. Some of these disease-free leaves had previously received dorsal or ventral incisions with a sterile scalpel and some were left undamaged.

The results showed :—

(1) Transmission of the organism in water-droplets is possible.

(2) Whereas the corky periphery of " shot-holed " tissue will not yield pathogenic organisms, lesions in the " grease-spot " or early " corky-phase " are infectious.

(3) The ventral surfaces of undamaged leaves are more susceptible to infection than are the dorsal surfaces.

(4) Leaves that have been previously damaged show infection symptoms after a shorter period than do undamaged leaves.

Leaflets of young disease-free plants in the forest, inoculated by the scalpel-wound method developed typical symptoms. Later examination revealed considerable infection of leaves below those artificially inoculated, but no infection was evident in the leaves above. In view of the fact that the pathogen is not systemic, it is inferred that transmission was effected by rain-drops.

DISCUSSION ON THE METHODS OF TRANSMISSION

Data from glasshouse and field experiments indicate that both contact with diseased tissue and water-carriage, i.e. in heavy dew, rain-dripping and wind-blown rain, are possible means of transmission of the disease under natural conditions.

These methods would, in general, be effective only over short distances and they appear inadequate to explain the presence of the pathogen throughout the discontinuous range of the host. Transport of the organism over long distances is doubtless possible by means of insects, birds or wind, although these appear far less positive than the methods cited above.

However, contact and water-carriage would have been quite adequate for spreading the pathogen throughout the range of the host if, as pointed out by Cockayne (1928), " —the (present) coastal tree florula is but a remnant of one much larger— ". Alternatively, it is not impossible that the organism has been associated with the host almost since its divergence from tropical ancestors and has accompanied it in its distribution.

Viability data have shown that the pathogen is capable of overwintering at lower temperatures and for longer periods than those recorded in any habitat of the host. Similarly, the viability of the organism is not affected by the higher temperatures and lower humidity of summer, since these conditions do not approach the extremes which the pathogen withstands under laboratory conditions. The environmental range tolerated by the pathogen is thus greater than that tolerated by the host. Therefore, once the disease has become established in a region, its complete extermination is unlikely, since constant local transmission would tend to keep the trees infected indefinitely.

Summed up, it appears that transmission is normally accomplished by " contact " methods and by transference of the pathogen in water-droplets (with or without the agency of the wind). In addition, birds or insects may be vectors. Any one, or possibly several or all, of these methods could account for dispersal.

DISCUSSION

The pathological condition of *Dysoxylum spectabile* is of special interest in that it is the only recorded example from the native flora in which a bacterial organism is the causal agent.

Extensive inoculations of other possible hosts have not been carried out but it appears probable that the pathogen is specific to this single host. As the host is endemic to New Zealand, the pathogen, if it is indeed specific to this host, is also endemic.

Although in the past little attention has been given to bacterial infection of native plants, it is not improbable that this disease of *D. spectabile* is one of many examples of pathological conditions induced by bacteria.

ACKNOWLEDGMENT

The author wishes to acknowledge the assistance given by Mr. J. B. Beveridge, Auckland City Council Ranger, in recording and measuring the lesions produced by the parasite in the leaves of *Dysoxylum*.

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PRELIMINARY REPORT ON USE OF PHOTOGRAPHIC EMULSIONS FOR RECORDING COSMIC RAY TRACKS AT HIGH ALTITUDES IN NEW ZEALAND

By J. W. BEAGLEY and A. C. STANBURY, Geophysical Observatory, Christchurch

(*Received for publication, 19th May, 1949*)

IN the latter part of 1948 six dozen nuclear research plates were obtained by the Geophysical Observatory from Ilford Ltd. with the object of launching a high altitude cosmic ray programme, hitherto not performed in New Zealand. This method of cosmic ray research has received much attention in recent years (1), (2), (3), and it is anticipated that the results obtained in this country will be of value for comparative purposes with the data recorded in the Northern Hemisphere. As a preliminary experiment the plates were distributed at various altitudes on the following mountains:—

Mt. Herbert	..	2,997 ft.
Mt. Rolleston	..	7,250 ft.
Mt. Ruapehu	..	9,100 ft.
Minarets ..	..	9,700 ft.

In addition it has been possible to expose plates between 25,000 and 40,000 ft. in a Mosquito aircraft. From the information recorded by these plates, data on the occurrence of various disintegration processes at each altitude will be obtained. The phenomena recorded by the plates are of course quite varied, but since a permanent record is obtained other projects are possible at any time from the same exposures.

During exposure, plates are merely placed in a suitable watertight container and left for an appropriate time at each site. No other equipment is necessary for this aspect of the programme as the cosmic rays penetrate the container and wrappings of the plates without noticeable effect. After a period which may vary from six weeks to two or three months (or in the case of the aircraft flights, only several hours) the plates are recovered and processed in a similar manner to ordinary photographic plates.

ACTION OF A COSMIC RAY PARTICLE IN THE EMULSION

The passage of a cosmic particle through the small silver halide grains of a photographic emulsion renders them developable, the density of grains depending on the rate of energy loss of such a particle (4). However, because of the great density of atoms in a solid as compared with a gas, their range in the emulsion is only about one two-thousandth part of the corresponding value in air. As a result, when the plate is examined under a microscope the tracks of the particles appear in the form of lines of black silver grains, the length of which depends on the energy of the cosmic ray particles.

Since the energy lost by a particle to an atom or group of atoms which it encounters depends on the time it takes to pass through the "sphere of action" of such atoms, it is found that a slowly moving particle will ionize more heavily (i.e. affect more grains) than a particle

of greater velocity carrying the same magnitude of charge. Thus, for example, a proton will, on the average, affect more grains in a given length of track than the lighter meson which travels much faster when the two particles possess the same initial energy. Since also the sphere of action is larger for a particle of greater charge, we find that a doubly charged particle will ionize more heavily than a singly charged one of the same velocity. Again, as a particle nears the end of its range it travels more slowly, and it is thus to be expected that the grain density would increase somewhat towards the end of the track. The plates used for this work are not capable of responding to electrons, since even low energy electrons move with tremendous velocities.

The above discussion illustrates the action of a cosmic ray particle in the emulsion, and provides a method for distinguishing between the tracks left by different particles.

DETERMINATION OF GRAIN DENSITY

In determining the grain density it is necessary to count, from the end of the track, the number of individual grains in successive intervals of some convenient length (about 50 μ) along the trajectory (5). If " N " is the total number of grains in a track of residual range " R," it is found that on plotting log N against log R for each interval, a series of points is obtained which lie on a straight line. Another track of greater grain density, hence higher value of log N, will give a line displaced from the other to a greater or lesser extent. Thus, since each particle gives rise to a definite grain density, this is a convenient method for identifying the various cosmic ray particles to which the tracks are due.

Owing to the variable concentration of active material in the emulsion the points seldom fall on a perfectly straight line. Again if the plates are not developed soon after exposure there is a fading of the latent image which reduces the density of the individual grains. It is found, therefore, that if several tracks are examined and plotted as described, the lines obtained fall into groups rather than being coincident.

Fig. 1 shows a group of meson tracks as observed in plates exposed for 36 days on Mt. Ruapehu. The dotted lines indicate roughly the positions of the groups of tracks due to α particles, protons, and mesons, as obtained by overseas workers (5).

INTERPRETATION OF COSMIC RAY TRACKS

If the plates are exposed for a short time and developed as soon as possible this method of interpretation is quite satisfactory. On the other hand, if the exposure time is fairly long and events are recorded some weeks before the plate is processed, the fading of the latent image becomes very important. It is apparent, for example, that when a proton track has faded sufficiently it would not be distinguishable from a newer meson track, as far as grain density is concerned. Thus too much reliance must not be placed on these data alone; more evidence of a different nature is necessary to be able to state definitely that a track was due to the passage of a particular particle through the emulsion.

The rate of increase in grain density at the end of a track is a characteristic of the particular particle involved. Thus, even though the track may have suffered a certain degree of fading, the particle to which it was due can be identified. The path followed by a particle is also to some extent a characteristic of that particle, e.g., a meson, being a light particle, is markedly deviated from a straight line by many elastic

collisions. A proton being much heavier is scattered very little and the increase in grain density at the end of its range is less marked than for the meson track.

Through such considerations, it is possible to interpret the events recorded by the plates with reasonable certainty. This method, however, calls for a great deal of tentative interpretation until the emulsion has been "calibrated." It is thus necessary to find quantitative characteristics of each type of track.

Unfortunately it is not yet possible to obtain sufficiently accurate grain counts to attempt this method of interpretation. It is necessary to be able to resolve the grains under the microscope to such a degree that an accurate count can be made. Overseas workers are using magnifications up to 2,000 diameters with the best possible resolving power.

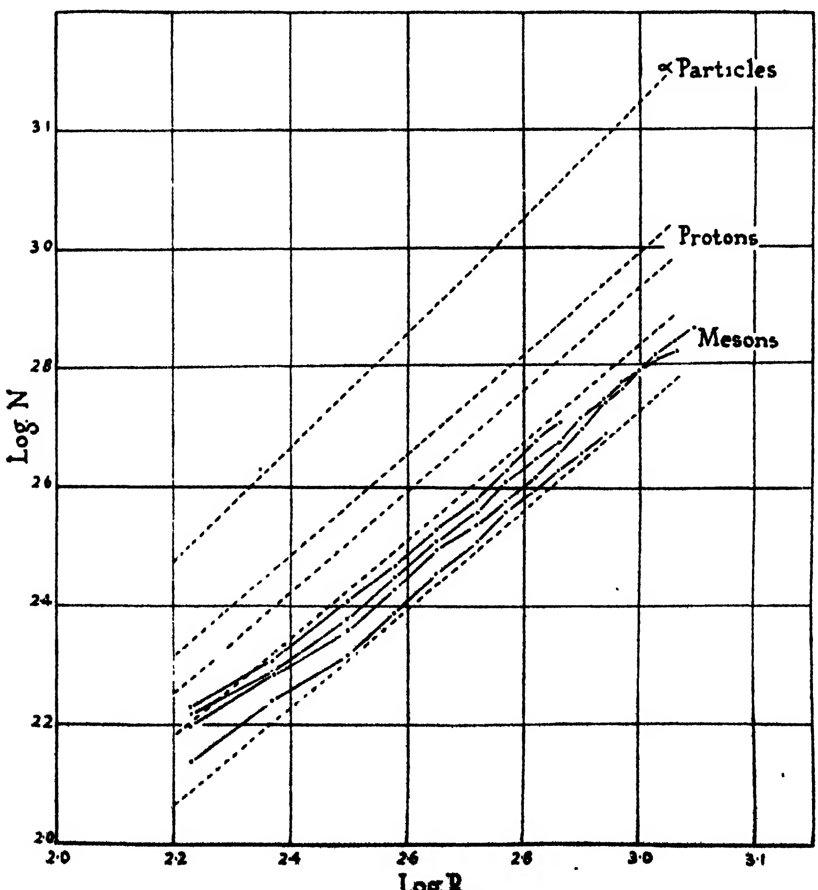

FIG. 1

It is unfortunate that at present such equipment is not available to the writers, who are, as yet, able only to take approximate grain counts of comparatively sparsely populated tracks (as those left by mesons). In Fig. 1 there are significant departures from a straight line along the various points recorded; these are in large part due to inaccurate counting owing to microscope limitations and, to a lesser extent, irregularities in the available grain concentration in the emulsion.

PHOTOGRAPHIC MOSAICS OF TRACKS

Until the required equipment comes to hand it is not possible to do much quantitative work, but in order to illustrate the type of phenomena recorded photographs of tolerable quality have been obtained. Two of them are reproduced with this paper. In order to produce such prints it is nearly always necessary to take several exposures and make up a mosaic of these to obtain the complete event. Such a procedure is required because all the tracks of an event are seldom in the same plane and the microscope has very limited depth of focus. When sufficient data is collected to "calibrate" the emulsion it will be possible to interpolate tracks of which perhaps only the first 100μ is visible. As yet, however, it is possible only to give a tentative interpretation of these events.

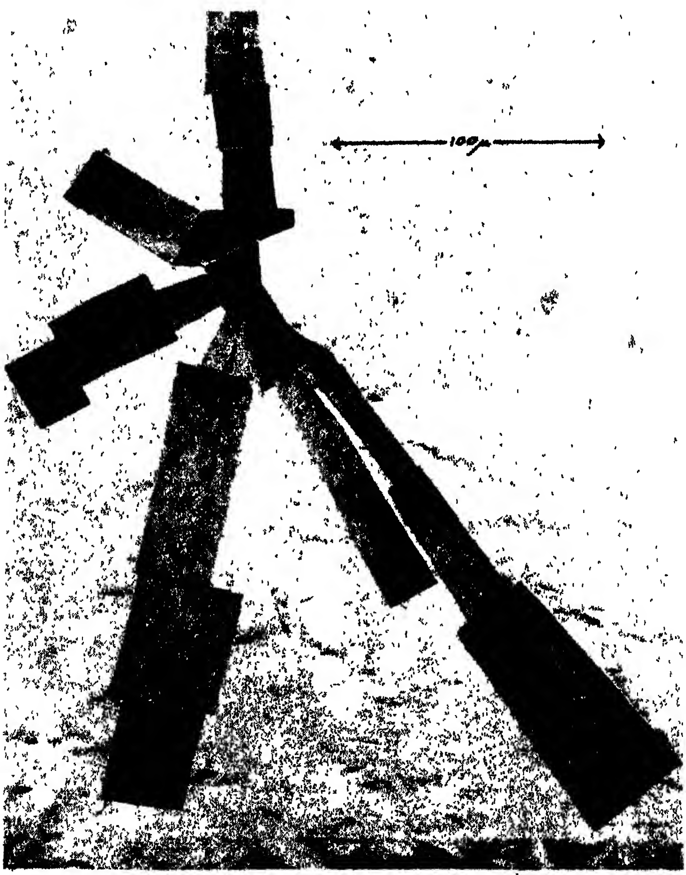

FIG. 2

Fig. 2 shows the result of a disintegration of a nucleus, possibly of oxygen, by a cosmic ray particle. The tracks are tentatively ascribed to four protons and two α particles. Three of the proton tracks pass out of the emulsion so that their range and hence their energy cannot yet be determined. The nature of the particle giving rise to this disintegration cannot be determined, although it will later be possible to estimate the energy required to produce the disintegration

Fig. 3 shows the disintegration of a heavier nucleus resulting in the emission of six protons, five α particles, and other heavier nuclear fragments. All tracks have not been reproduced in full as some are too weak to be recorded with the present photographic technique. This event has suffered some degree of fading and all tracks are somewhat thinner than would be expected. The change in direction of one of the α particle tracks indicates that it has suffered an elastic collision with the nucleus of an atom of the emulsion. One of the proton tracks has also been deflected but to a much less marked degree. Such encounters are comparatively rare as can be judged from the many other long straight tracks of these two events. There are in all 14 tracks from this disintegration visible in the original; only five of these end in the emulsion, the others terminating on one of the surfaces. Since some of the tracks dip more steeply in the emulsion than others, these two dimensional pictures give a false impression of grain density.

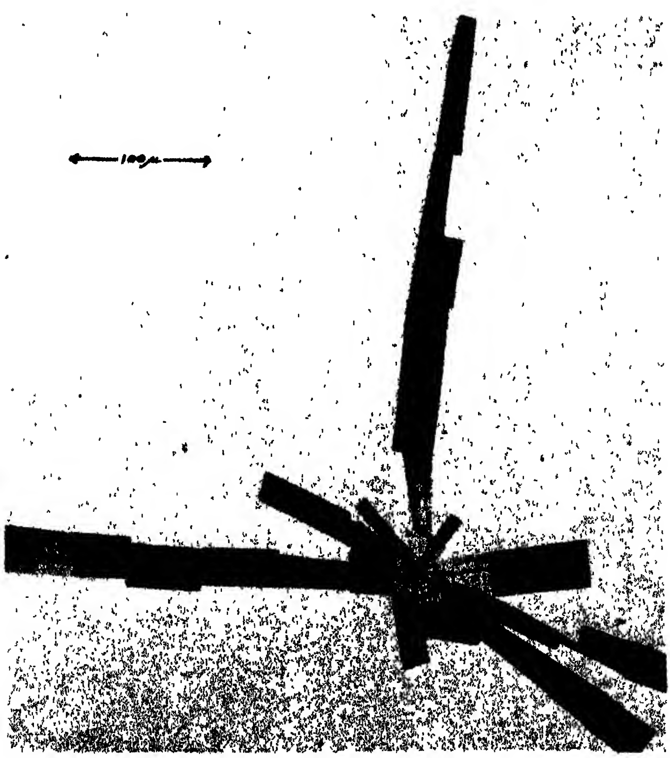

FIG. 3

In addition to those plates exposed without any shielding material, there are some now in the course of exposure under a layer of paraffin in order to obtain disintegrations by neutrons in the emulsion, and others under lead, to study the secondary effects of showers produced in the lead.

FUTURE WORK

It is hoped in the future to obtain more information of this type if these preliminary experiments are fruitful. Plates will be shielded by different materials, and distributed at various altitudes in order to cover as much of the cosmic ray spectrum as possible.

It was found that the photographic technique yields an enormous amount of material with a minimum of effort and expense. The interpretation and analysis of the results, however, is a slow process; it is possible to examine only about 1 cm^2 of the plates per day. On one of the plates examined to date, exposed on Mt. Ruapehu it was found that 54 " stars " and many other single tracks were recorded on 0.5 sq. cm. of the plate.

ACKNOWLEDGMENTS

The writers wish to acknowledge the co-operation of the Canterbury Tramping Club and the Guides at the Hermitage in placing the plates on Mt. Rolleston and the Minarets. Thanks are also expressed to the Agronomy Division at Lincoln, Canterbury, for the use of a microscope without which this preliminary work would not have been possible.

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SOME OBSERVATIONS ON E REGION EFFECTS

By A. L. GARDNER, Geophysical Observatory, Christchurch

(*Received for publication, 12th March, 1919*)

ECHOES observed in the region below about 200 kilometres are frequently complex and show considerable stratification into well defined and separate regions. At observatories of the New Zealand Department of Scientific and Industrial Research regions under F1 are interpreted as being from either E1, E2 or Sporadic E.

Christchurch

With the exception of the Christchurch Station (43.5°S. 172.7°E.) none of the New Zealand stations has been in reliable operation for a sufficiently long enough time for a detailed examination of results to be made. Lincoln (Christchurch) automatic recorder has been in operation since November, 1944. Previous to that the recorder used was a lower powered and less reliable model.

Fiji

A recorder similar to the Christchurch equipment was operated for one year at Tamavua Valley (18.0°S. 178.2°E) near Suva but owing to equipment and servicing difficulties the recorder has been dismantled. Results obtained were not consistently good.

Campbell Island

This station, a manual type, was for a considerable time the highest southern latitude station, being located at 52.5°S. 169.2°W. Observations prior to 1947 were, during some periods, somewhat doubtful.

Rarotonga

The Observatory (21.3°S. 159.8°W.) here was established to check foF2 values with Maui, Hawaii and observations were largely confined to F2 in the early period. However, during the past year full results have been obtained from the new manual equipment.

Raoul Island

May, 1943, saw the establishment of this manually operated station at 29.3°S. 177.9°W. but until a year later only partial results were obtained. The station was closed in March, 1947.

Pitcairn Island

A manually operated station at Pitcairn (25.0°S. 130.0°W.) was operated for nine months during 1944 and 1945. Owing to inexperienced staff no great detail could be obtained from these records.

Automatic Ionosphere recorders have the advantage that recordings are taken at constant speed and with constant receiver gain. On the other hand there is little indication of amplitude of received echoes. The careful recording of echo amplitude at manual observatories showed that Sporadic E traces could be divided into several types. Two main types of Sporadic E echoes were observed. These are called "intense" and "normal" respectively.

INTENSE SPORADIC E

The intense type of Es has strong echoes and multiple reflections were almost invariably present. At Raoul Island, where most of the observations were made, intense Es frequently formed by the gradual lowering in height of strong E2 region echoes. It was found that if in the early morning E2 echoes were very strong there would certainly be a change into intense E2 later in the day. As the virtual height of E2 decreased the penetration frequency increased slowly and the cusp in the curve became less well defined. The next change was usually that the trace appeared more like a Sporadic region in that there was no retardation at the point where the layer was penetrated and usually the Es and F1 traces overlapped by .1 or .2 mc./s. About this stage the ordinary and extraordinary ray traces ran together and the trace may be said to have become truly Sporadic E with a virtual height of 115 to 140 kilometres. Most usually the ionosphere remained in this state for several hours but occasionally the maximum frequency at which echoes were received increased rapidly, usually blanketing a considerable portion of the F region trace. In the early part of the day fEs frequently oscillated between high and low values but towards evening usually became strongly ionized for considerable periods. With this type of Sporadic E the E1 region trace was usually unaffected.

If the frequency at which the E Sporadic region is partially penetrated (blanketing frequency) is below foF2 so that echoes after penetration are returned to the recorder, it is usually found that echoes drop sharply in amplitude when penetration occurs, with a second drop of .9 to 1 mc. later where the extraordinary ray penetrates. In most cases echoes do not continue past this frequency but occasionally a weaker echo may persist. This would indicate that the ordinary and extraordinary ray traces are still separate although they cannot be resolved by the equipment.

Echoes received from this type of Sporadic E are usually very sharply defined and show no tendency to scattering.

Intense Es is also formed below the E1 region. The formation and disappearance of this type is more erratic than the behaviour of the previous type. The main distinguishing feature between the two types of trace is that with this type E1 echoes are usually blanketed. Occasionally a rather poorly defined inflection is seen in the curve .3 to .5 mc. below what would normally be the E1 penetration frequency for the hour observed, but this is not regarded as being foE1. When the Sporadic E trace fades this inflection disappears. With this type of Es strong echoes usually continue to a considerably greater frequency than that at which penetration of the region occurs. The penetration is usually gradual and the exact frequency at which it occurs is difficult to determine as the first echoes from F region " grow " slowly in amplitude. Sporadic E echoes of this type frequently persist for many hours or even several days. Scattered echoes are not uncommonly observed especially at the upper frequencies. Occasionally scattered echoes appear as a false cusp in the curve due to the vertical incidence echoes passing completely through the region while echoes are still returned at slightly oblique angles.

NORMAL Es

(*a*) *Above E1*

A very common type of trace with weak echoes usually persisting for less than one megacycle above E1 penetration frequency. It may occur in every record on days when it is observed and with the approach of evening will form type "b."

(*b*) *Night-time Es*

A relatively weak and scattered echo which may persist all night but often disappears soon after midnight. The upper frequency is usually between 2 and 3 mc./s. and does not change much with time.

(*c*) *Early Morning Es*

About dawn when absorption is very low a very scattered echo is almost invariably observed. These echoes frequently obscure E1 and E2 traces for about two hours after dawn.

At Christchurch the E region trace is almost always obscured by a scattered, weak reflection extending from about 70 km. through to 150 km. or more. Loop measurements of direction of arrival indicate that these echoes are probably from the Southern Alps which lie about 70 km. from the recorder.

FREQUENCY OF OCCURRENCE OF Es

The records from all the New Zealand stations were examined to check on the frequency of occurrence of intense Sporadic E. For convenience Sporadic E which continued in frequency past 7 mc./s. was taken as the measure of Sporadic E activity. The percentage of occurrences was calculated for each hour during each month. The figures for each hour were then added to give an activity figure for each month. Christchurch was the only station in operation for any considerable period and the results from this recorder are reproduced in Fig. 1.

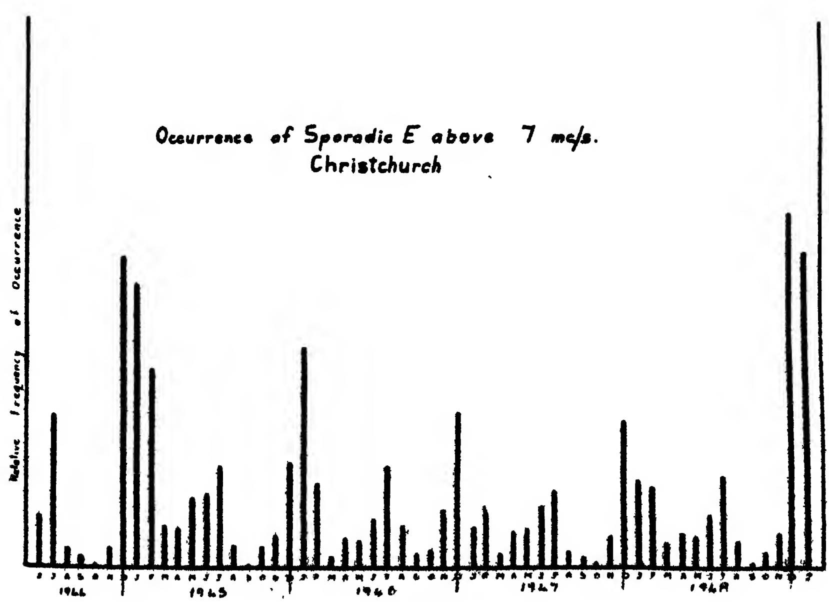

FIG. 1

The figure shows very clearly that there is a summer maximum of activity with a lesser maximum in midwinter. The Spring minimum in September-October is much better defined than the flatter Autumn minimum. Of the fifty-six months examined there were only three during which no Sporadic E was observed above 7 mc./s.

It would appear that Sporadic E activity at Christchurch is at a maximum during the sunspot minimum and that activity decreases during the rise of the sunspot curve. The two months of highest activity which do not fit the general pattern, December and January, 1949, were also months of unusually disturbed F2 conditions.

OTHER STATIONS

Although shorter periods were observed at other stations, in general the form of the curve of activity appeared similar in all cases. Fiji station had much more intense Sporadic E than Christchurch during its year of operation whereas values from Raoul Island were less. Campbell Island records are less complete but it appears that the variation there is less from month to month and the peaks of activity occur one month later.

CONCLUSION

While as yet only a comparatively short period of time has elapsed during which recordings have been made it is obvious that continued operation of the island stations will give information about the spatial and time distribution of Sporadic E activity, uncomplicated by any possible land mass effects.

This work was carried out as part of the programme of the Geophysical Observatory, Department of Scientific and Industrial Research.

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OLEO-CASEIN PAINT

By W. R. MUMMERY, Dairy Research Institute (N.Z.), Palmerston North

(*Received for publication, 21 December 1948*)

Summary

An oleo-casein paint consisting of a linseed oil in water emulsion stabilized by a casein solution and mixed with a pigment blend of lithopone, whiting and barytes gave satisfactory results as a road traffic paint, replacing for some purposes during the war years the previously employed organic solvent paint, thus assisting in conserving the supplies of benzene and alcohol. Potassium dichromate, added as a hardening agent for the casein, increased the durability of the casein film. The paint has been used for coating bridge approaches, kerbs, lamp standards, telegraph poles and the interior of milking sheds. If only high grade pigments are used, it can be employed as an interior coating in dwelling houses, offices and stores and also, under good atmospheric conditions, in factories.

INTRODUCTION

THE use of casein in the preparation of water paint has been practised for many centuries. Michael Angelo, for instance, is said to have employed a combination of sour milk, oil and pigments for producing high light effects in mural decorations (1). As a commercial product oleo-casein paint was introduced about 30 years ago. Casein is used as the spreading agent in the formation of an oil-in-water emulsion to serve as a vehicle for the pigments and to assist in the formation of a durable film. Oleo-casein paint is sold in paste form at about half the price of oil paint and is regarded as a useful intermediate between oil and water paint.

The manufacture of oleo-casein paint has proved successful in the United States and Europe where the product has received care and attention throughout each stage of the process. In the former country, interest was stimulated by the extensive use of exterior casein paints at the Century of Progress Exhibition at Chicago in 1933 and 1934, where flat paints were required for night illumination. In New Zealand prior to 1939 there were several proprietary brands of oleo-casein paint on the market, but the majority were irregular in quality and showed many defects which included lack of durability, decomposition during storage and sedimentation of pigments. The present investigation arose out of a shortage of certain ingredients of paint used for marking roads, bridges and for general road-safety marking purposes. The paints required were of the two following classes:—

(1) *Traffic line paint* which required the utilization of natural gums dissolved in a vehicle such as petroleum spirit or denatured alcohol, for asphaltic, bitumen or tarred surfaces.

(2) *General service roadside paint* which with an oleo-casein base was to be serviceable for kerbs, bridge approaches, fences, lamp standards and telephone poles and was to be prepared, if possible, from ingredients which could be supplied locally.

The Wellington District Committee for Paint Investigation was requested to investigate the composition of casein paint in order to produce a suitable specification that could form an emergency standard for a general service, or roadside traffic paint (class (2) above). As a preliminary, samples obtained from all the New Zealand manufacturers of casein paint were tested for resistance to traffic abrasion and for water-resistance.

EXPERIMENTAL TECHNIQUE

Preliminary Tests

Traffic Abrasion Test

This test was made with the use of an electric turn-table of diameter, 12 in., on which could be placed a metal plate coated in sections with different samples of paint and with a control sample of known quality. When the table was set in motion an arm bearing a small iron trolley-wheel was lowered until the wheel touched the moving metal plate and was likewise set in motion. The apparatus was run for a standard period of time. The condition of the surfaces was then examined and compared with that of the control sample.

Water-Resistance Test

One full coat of the paint was applied to the surface of a smooth red facing-brick and was allowed to dry for two hours at normal room temperatures (60-65° F.) and at a relative humidity of not less than 85 per cent. It was then subjected for 15 minutes to a spray of cold water issuing from the bottom of a one-gallon container, through 25 holes, each spaced at one-inch intervals in the form of a four-inch square. During the test the water container was suspended so that the spray fell 24 in. to the painted surface of the brick.

Development of New Formulae

The proprietary paints did not pass either the abrasion or the water-resistance tests. Attempts were therefore made to find an improved formula. The work, consisting of three series of trials, may conveniently be considered under the following six headings.

(1) *Composition of Vehicle*

Casein.—Lactic casein was found to be effective as an emulsifying and a binding agent for paints to be used on surfaces that are comparatively non-absorbent. When the surface for painting was porous, however, as on certain types of building board, it was found necessary to use animal glue with the casein. Equal parts of casein and animal glue make an excellent combination for this purpose. The film produced by casein alone was found to be brighter and more water resistant than that containing a proportion of animal glue and therefore casein was used in Series 2 and 3 whenever possible. Previous work on developing

a casein surfacing for butter boxes suggested a formula utilizing ammomium carbonate and sodium tetraborate (borax) as the solvent agents.

Oil.—Paints made with tung oil were found to produce a more durable film and to permit less fungal growth than paints made with addition of the same proportion of linseed oil. However, as at that time tung oil was in short supply, linseed oils were used in most of the experimental paints. It was found that a satisfactory emulsion with water could be obtained with raw and boiled linseed oils in equal proportions. One part of the mixed oils was emulsified with three parts by volume of water. An appreciable increase in proportion of oil above 30 per cent by volume reduced the durability of the paint in several experiments, with exterior coatings, indicating that the emulsion of oil in water is more stable in the proportions of not more than one volume of oil to three volumes of water.

(2) *Composition of Pigment Blend*

The following pigments were available:—Lithopone, zinc oxide, titanium dioxide, whiting, barytes, kaolin, silica and white portland cement.

Lithopone.—The best sample of paint for exterior work found during the investigation contained 70 parts of lithopone in 100 parts of pigment blend. This pigment showed good durability and opacity. The superiority of the sample was due largely to the insolubilizer, i.e. the agent used for rendering the casein more resistant to weathering (see below). This statement, however, does not detract from the good qualities of lithopone in specific proportions for this class of paint.

Zinc oxide.—Zinc oxide in oleo-casein paint contributes durability and hiding power; it also has a fungicidal property.

Whiting.—Whiting is opaque in oleo-casein paint and therefore acts as a true pigment and not merely as a filler. For this reason the whiting employed must be of high quality. During the 1939-45 War, stocks of first-grade whiting became depleted and when the problem was first considered it seemed necessary to use New Zealand whiting. The use of New Zealand whiting, however, resulted in loss of whiteness in the paint and, for locations where it was necessary to maintain the original whiteness, half of this pigment was replaced with a first-grade kaolin.

Titanium dioxide.—In this investigation titanium dioxide has been used, blended with other pigments such as lithopone and zinc oxide, to produce a paint suitable for interior surfaces.

Kaolin.—Kaolin was used successfully for mixing with inferior grades of whiting to improve the hiding property. Kaolin of high quality was obtained from a local source.

Barytes.—Barytes was employed for replacing some of the whiting in order to increase the resistance to abrasive action. It also increased resistance to weathering.

Silica.—A pure white quartz was used as one of the pigment ingredients in the first series. It increased the durability but it lacked the opacity-giving quality of whiting or Kaolin. Diatomaceous earth, another form of silica, improves the brushing properties.

White Portland cement.—Incorporation of white portland cement increased the durability but lowered the spreading rate. After six months' application the white appearance had given place to a cream tint.

(3) *Inhibition of Sedimentation of Pigments*

Bentonite.—Asbestine is recommended in the literature for preventing sedimentation in paints, but it was not obtainable in New Zealand. It was found that bentonite, a clay formed (usually) from the decomposition of volcanic ash and consisting of a mixture of clay minerals present as extremely minute flakes, had similar properties. Paints containing bentonite in the proportions of 10, 5 and 2.5 per cent of the pigments were compared with a control sample not containing bentonite. A proportion of 2.5 per cent of bentonite in the pigment was found to be sufficient to prevent sedimentation, and the consistency of this paint was found to be superior to the control and also to paints containing the larger proportions of bentonite.

(4) *Provision of Suitable Agent for Increasing Durability*

The durability of casein paints can be increased by the addition of agents to make the casein and animal glue insoluble. For this purpose, a mixture of formaldehyde and ammonia has been used for some years. Sutermeister and Browne (2) report the use of chromates and they state that the casein is made insoluble by the action of light. Floyd and Shore (3) state that oxidizing agents such as potassium permanganate and hydrogen peroxide, under certain conditions will remove the amino group from amino acids and that this is accompanied by oxidation of the carbon atom to which the carbonyl group is attached. In the present investigation it was found that oxidation of the protein could be effected by the addition of potassium dichromate to the vehicle in the proportion of 0.4 per cent by weight and that this improved the durability of the paint film. The use of an equivalent amount of the sodium salt is recommended as the price is lower; at this period it was unobtainable.

(5) *Provision of Suitable Preservative for Prevention of Deterioration during Storage after Manufacture*

The preservative most commonly used in New Zealand in proprietary brands of oleo-casein paint has been phenol. Phenol has the disadvantage of a penetrating odour and if used in adequate quantity to preserve the paint in paste form the odour is too strong to permit of the paint being applied in shops, warehouses, or factories where foodstuffs are stored or prepared. An oleo-casein paint preserved with phenol when used for the coatings of ceilings in a dwelling flat was found to emit a strong odour of phenol for six weeks after the application of the paint. In the investigations under consideration, trials were carried out with (1) phenol, (2) "Lysol," (3) "Shirlan W.S." (sodium salt of salicylanilide), (4) "Chenol A" and (5) cresylic acid. Cresylic acid was the only preservative found to be effective in reasonable proportion, a paint containing one fluid ounce per gallon of vehicle being free from odour. During the investigation, the wall of a butter room in a dairy factory has been painted while the butter was being taken from the churns and packed in boxes for export. With the use of either an ordinary oil paint or of oleo-casein paint containing phenol this procedure would have been impossible without causing taint in the butter. Oleo-casein paint preserved with cresylic acid was found to be in good condition two years after manufacture.

(6) *Provision of Suitable Fungicide for Prevention of Mould Growth on Paint after Application*

Difficulty was experienced in 1940 in obtaining a wide range of chemical compounds reported as having fungicidal properties. The fol-

lowing range of substances was tried:—(1) Mono-chlor-iso-thymol, (2) "Shirlan W.S." (sodium salt of salicyl-anilide), (3) "Chenol A," (4) sodium trichlorophenate and (5) sodium pentachlorophenate. Various proportions of fungicide were incorporated in oleo-casein paint prepared with linseed oil, lithopone and whiting but without preservative or insolubilizer, and several controls without fungicide were also prepared. The paint samples, including the control samples without fungicide were inoculated with several species of fungus and were then applied to small tiles and wood blocks. The latter were kept in bell jars at room temperature at a high humidity. Under these laboratory conditions, sodium pentachlorophenate was found to be the most effective fungicide. It inhibited mould growth when present in the paint in a concentration of one-half per cent. Practical trials on a larger scale showed that this concentration of fungicide was not sufficient for situations or conditions where infection from mould spores was considerable. Further trials of paints containing a larger proportion of fungicide were then made in a dairy factory on a concrete wall subjected throughout the season to warm moist air currents from a mechanical can-washer. The surface of the wall was first marked off into two portions for coating with two different samples of oleo-casein paint, and each portion was sub-divided into four panels. The panels were coated with paint containing (a) no fungicide, (b) one per cent, (c) 1.5 per cent, and (d) two per cent of sodium pentachlorophenate. Inspection after twelve months showed that two per cent of sodium pentachlorophenate was necessary to inhibit mould growth but that this quantity produced a cream tint. Mercuric chloride was then tried as a fungicide but it produced a brown efflorescence on the surface of the paint probably due to interaction of the mercuric chloride with sulphur in the casein to form mercuric sulphide.

DETAILED RESULTS

Three series of trials were made:-

Series I and II.—The objective was to find a formula for an oleo-casein paint to serve as a general exterior traffic paint for coating roadside kerbs, bridge approaches, fences, lamp standards and telephone poles. These trials included the testing of proprietary casein paints and methods for ascertaining the general suitability of oleo-casein paint for exterior work.

Series III.—A study of the suitability of oleo-casein paint for interior surfaces of dairy factories.

Series I. Oleo-casein Paint for Exterior Use

Paints were made according to 25 different formulæ. Twenty-four had the same vehicle but different pigment blends, and two of these were treated, each with a different insolubilizing agent. The remaining paint of the 25 was prepared with rubber solution as the vehicle. The paints contained preservative to prevent deterioration in bulk, but no fungicide to protect the film after application. Test pieces of dressed timber (24 in. by 5 in.), concrete tiles, bricks and cement asbestos-board were painted with two coatings, and were exposed on wooden trestles to a northerly aspect for two years, in the grounds of Massey Agricultural College.

Test pieces of timber (8 in. by 4½ in.) and bricks were exposed in the milk-bottling room of Massey Agricultural College dairy factory. Five of the 25 paint samples were found to be of good quality. Their composition is shown in Table I together with that of one unsatisfactory paint of particular interest (No. 19).

TABLE I. PERCENTAGE COMPOSITION OF SIX PAINTS USED IN SERIES I

Paint Sample No.	8	9	10	14	18	19
Pigments (per cent.)	65	53	53	65	59	59
Vehicle (per cent.)	35	47	47	35	41	41
Weight per gallon (lb.)	17	16	15	15	16	16
Volume of water to thin 100 parts of paint paste	20	20	14	20	20	20
Percentage Composition of Pigment Blends.						
Lithopone	70	70	—	57	70	70
Zinc oxide	—	30	45	—	—	—
Whiting	30	—	45	23	30	30
Titanium dioxide (98-100 per cent.)	—	—	10	—	—	—
Silica	—	—	—	20	—	—
Percentage Composition of Vehicle.						
Raw linseed oil	—	10	10	10	10	10
Pale boiled linseed oil	—	10	10	10	10	10
Tung oil	22	—	—	—	—	—
Casein, solvents, glue	6	6	6	6	6	6
Water	72	74	74	74	66	66
Pot. bichromate (5 per cent.)	—	—	—	—	3	—
Formaldehyde (15 per cent.)	—	—	—	—	—	1

Paint No. 18, containing potassium dichromate as insolubilizer, showed excellent durability over a twelve-month period of exposure, and it was found to yield a film giving satisfactory abrasion and water-resistance tests. This paint has been taken as the standard reference paint in the New Zealand Standard Specification N.Z.S.S. E.67 (1940). The condition of a number of the paint films after exposure to weathering for two years is shown in Figs. 1-3 and in Table II.

Trials on Dressed Timber Panels (Fig. 1).—The panels with the best appearance were Nos. 5, 8, 9, 9x and 24. Paint film No. 8 was the best of those without an insolubilizing agent, as the tung oil increased the durability. Film No. 9 was also good and had no insolubilizing agent; the use of extra vehicle in place of water for thinning the paints, as shown by No. 9x, did not improve the paint film. Film No. 24 was attractive but showed heavy chalking. Further work on this formula was abandoned owing to the unprocurability of scrap rubber. The appearance of film No. 18 was spoilt by a heavy growth of mould.

Trials on Bricks and Concrete Tiles.—Figs. 2 and 3 show trestles bearing the coated bricks and concrete tiles. Superiority of the film No. 18 is shown distinctively by the white opaque appearance on both brick and tile. Paint films Nos. 8, 9 and 24 exhibited good appearance and condition on both building materials, while No. 14 showed good appearance and condition on concrete. Seven paints were thinned with water and also with vehicle, the latter being marked with an X. Paint

TABLE II. RESULTS FOR DURABILITY TESTS OF PAINTS (1ST. SERIES) AFTER TWO YEARS EXPOSURE

Exterior Exposure. Palmerston North.

Type of Surface Painted.	Results for Paint Nos.					
	8	9	10	14	18	19
Concrete tiles	Fair appearance and condition	Failure	Failure	Good appearance and condition Slight chalking	Good appearance Slight chalking *1st. preference*	Poor appearance Bad chalking
Bricks	Fair condition and appearance Slight chalking	Fair condition and appearance Slight chalking *1st. preference*	Failure	Fair appearance and condition Chalking	Fair condition and appearance Slight chalking	Failure
Cement asbestos board	Fair condition	Failure	Fair condition	Failure	Good appearance and opacity Slight chalking *1st. preference*	Failure
Wood panels (dressed timber)	Good appearance and opacity Slight chalking *1st. preference*	Fair appearance and opacity	Failure	Failure	A Good film spoilt with fungoid growth	Failure

Interior Exposure. Dairy Factory, Palmerston North.

Type of Surface Painted.	Results for Paint Nos.					
	8	9	10	14	18	19
Bricks	Good condition Change from white to cream colour	Excellent appearance White	Excellent appearance White	Good condition Change from white to cream colour	Excellent appearance White colour	Excellent appearance White colour
Wood panels (dressed timber)	Good condition Change from white to cream colour	Good condition Change from white to cream colour	Good appearance White	Good condition Change from white to cream colour	Excellent appearance White colour	Good appearance White colour

films Nos. 9x, 10x, 11x and 17x showed a similar appearance and condition to films Nos. 9, 10, 11 and 17, while films Nos. 5x, 11x, 12x and 13x showed more signs of weathering than the films Nos. 5, 11, 12 and 13. Although this custom of the paint trade appears to have been unwarranted in the past, further work on this phase of the subject has shown that if the vehicle contains potassium dichromate the procedure is advantageous. Reference has been made already to the use of another agent, formaldehyde, for promoting durability of the paint film; this ingredient was used in making paint No. 19 and proved unsuccessful for exterior work. It was, however, used with advantage for interior coatings as shown in Table II.

FIG. 1.—Paint Films from two Coatings on Dressed Wood Panels (Series 1, Nos. 1-25) after Weathering for two years.

Series II. Oleo-casein Paint for Exterior Use

Paints were made according to 10 different formulæ. Four had the same pigment blend but different vehicle, and six had the same vehicle as No. 18 and potassium dichromate agent, but different pigment blends. All paints contained preservative and fungicide. Trials for durability were made by exposing test pieces, as previously, in the grounds of Massey Agricultural College. Test panels also were painted on the west wall of the rail-car shed, Wellington station. On the rail-car shed wall each panel was divided into two halves so as to observe the difference in hiding power between one and two coatings. Table III shown below gives the composition of the five best paints out of the ten tested in Series II, Nos. 31-40.

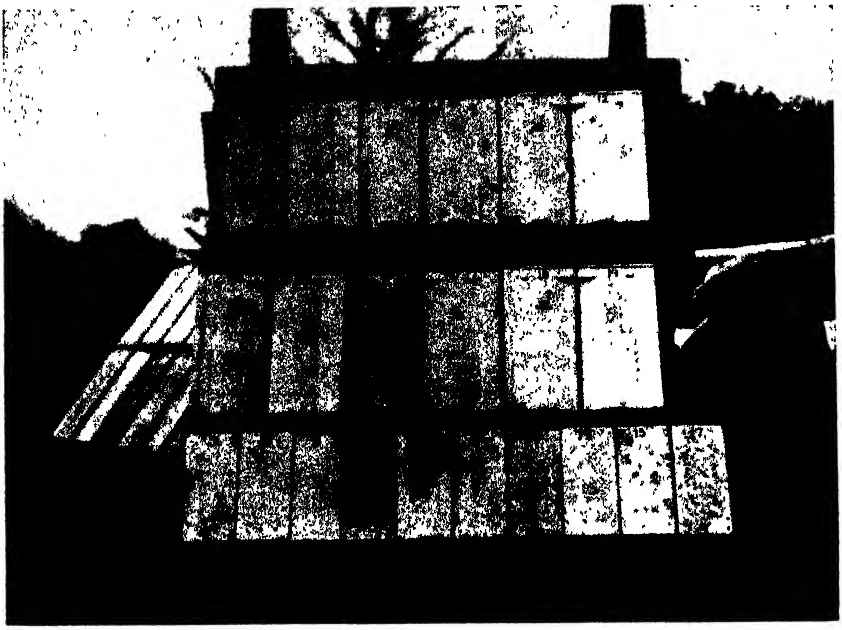

FIG. 2.—Paint Films from two Coatings on Concrete Tiles and Bricks (Series 1, Nos 1-25) after Weathering for two years (Compare also Fig. 3.)

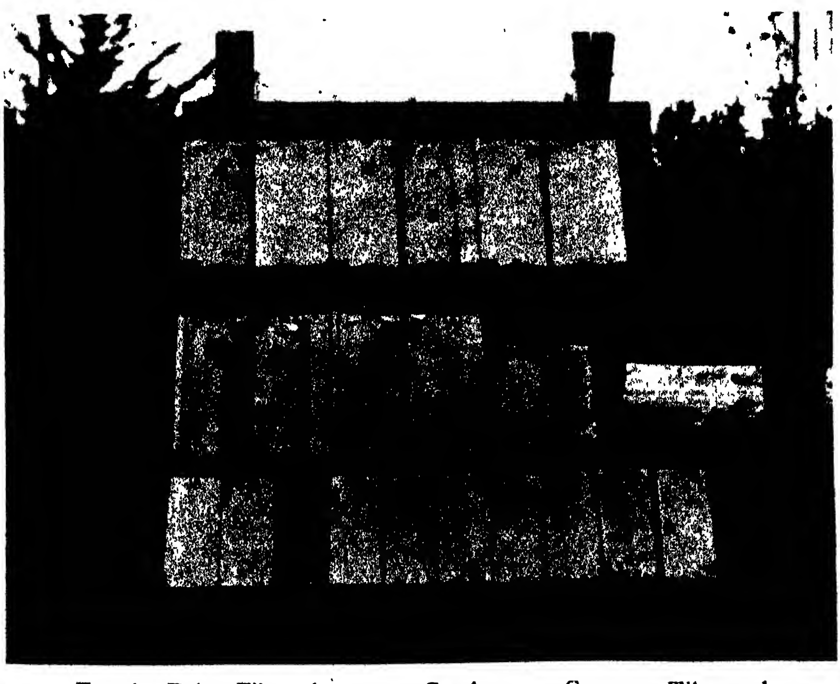

FIG. 3.—Paint Films from two Coatings on Concrete Tiles and Bricks (Series 1, Nos. 1-25) after Weathering for two years. (Compare also Fig. 2.)

TABLE III. COMPOSITION OF FIVE BEST PAINTS, SERIES II TRIAL, NOS. 31-40

Paint Sample No	35	36	37	38	39
Pigments per cent.	64	64	64	64	64
Vehicle	36	36	36	36	36
Weight per gallon, (lb.)	17	18	16	17	17
Volume of water to thin 100 parts of paint paste	30	30	30	20	30
Percentage Composition of Pigments					
Lithopone	45	40	20	70	70
Zinc oxide	20				20
Whiting	30	30	40	25	
Titanium dioxide (98-100 per cent.)		10			10
Kaolin			40		
Barytes		20		5	
Portland cement (white)	5				

Analyses of four of these paints were made in the Dominion Laboratory, Wellington, and the results are shown in Table IV.

TABLE IV. ANALYSES OF THE FOUR BEST PAINTS OF THE SECOND TRIAL, NOS. 31-40

Paint Sample No.	35	36	38	39
1. Coarse particles held on B.S No. 240 sieve, per cent.	0·5	0·6	0·9	1·0
2. Weight per gallon (lb.)	18	18	18·5	18·2
3. Hiding power, checkerboard brushout (sq. ft /gal.)	220	240	200	270
4. Spreading rate, unsealed plaster (sq. ft /gal)	150	190	220	200

All these paints were satisfactory in respect of brushability on non-absorbent surfaces, brightness, resistance to dry rubbing, recoating, resistance to striking and keeping qualities. When applied over a primed wood surface, the dried film of No. 35 had a somewhat mottled appearance and was of a darker tint than the others which gave very satisfactory finishes on the same surface.

It is apparent from Table V that paint No. 38 showed excellent durability in the exterior tests. The composition of this paint was a slight modification of No. 18, substituting five parts of barytes for five parts of whiting. The paint passed a test in the accelerated weathering apparatus at the Dominion Laboratory and the formula was accepted for the standard reference paint in the New Zealand Standard Specification. N.Z.S.S. E102 (1942). Paint No. 39 gave the best results in the interior tests and also for covering cement asbestos-board in the outdoor trials.

Series III

Opportunity for further confirmatory work was provided by a request to determine the suitability of oleo-casein paint for coating the interior of dairy factories and milking sheds. Two butter factories and one milking shed were made available.

Factory No. 1 was coated over the whole of the interior with paint No. 39. Two coats were necessary to give the required finish. After 12 months it was considered advisable to repaint a portion of the west wall which was damp from weather conditions, and also a small patch on the east wall that had been affected by steam. After three years the

TABLE V. RESULTS FOR DURABILITY TESTS FOR PAINT NOS. 35, 36, 37, 38 and 39, AFTER 18 MONTHS EXPOSURE

Exterior Exposure. Palmerston North.

Type of Surface Painted.	Results for Paint Nos.				
	35	36	37	38	39
Concrete tiles	Good appearance and condition	Good appearance and condition	Fair appearance and condition Slight flaking	Fair appearance and condition Slight flaking	Fair appearance and condition Slight flaking
Bricks	Poor opacity Slight chalking	Good appearance and condition		Good appearance and condition	Poor opacity Slight chalking
Cement asbestos board	Fair appearance and condition Slight chalking	Fair appearance and condition Slight chalking	Good appearance and condition	Good appearance and condition	Good appearance and condition
Wood panels (dressed timber)	Fair appearance and condition	Failure	Fair appearance and condition	Fair appearance and condition	Fair appearance and condition

Exterior Exposure. Wellington.

Type of Surface Painted	Results for Paint Nos				
	Benzene (control)	35	36	38	39
Concrete wall	Fair hiding power Slight chalking	Good condition Fair appearance	Fair hiding power Slight chalking	Good appearance and Excellent condition Good opacity with one coating	Excellent appearance and condition Good opacity with one coating

Interior Exposure. Dairy Factory, Palmerston North.

Type of Surface Painted	Results for Paint Nos.				
	35	36	37	38	39
Bricks	Excellent appearance, condition and colour	Excellent appearance, condition and colour	Excellent appearance, condition and colour	Good appearance, condition and colour	Excellent appearance, condition and colour
Wood panels (dressed timber)	Change from white to cream tint	Good appearance, condition and colour	Change from white to cream tint	Good appearance, condition and colour	Excellent appearance, condition and colour

REVIEW

VOLCANIC STRATA AS A NEW METHOD OF POST-GLACIAL CHRONOLOGY IN TIERRA DEL FUEGO.

Las Capas Volcanicas Como Nuevo Metodo De Cronologia Post-Glacial en Fuegopatagonia. Vaino Auer. Publication No. 6 of the Ministerio de Agricultura de la Näción, Buenos Aires, Argentine, 1948.

'In science one must have luck—hard work alone is not sufficient.' This comment occurs in a 26-page paper by Dr. V. Auer in which he sums up the results of an investigation carried on over a period of twenty years. When boring for samples for the first time in the neighbourhood of the River Grande, three volcanic layers were found in the same swamp, one above the other and with strata of peat between them.

These volcanic deposits represented three distinct eruptions (or rather groups of eruptions for they were not exactly simultaneous over the Southern Andean volcanic region) and it was eventually possible to say that they occurred more or less 9,000, 4,000 and 2,000 years ago respectively. To this extent the chronology of the eruptive strata of Fuegopatagonia is now complete.

About 200 profiles were studied by pollen analysis, the samples, taken at 5 cm. intervals, amounting to some thousands. The pollen diagrams, correlated with the aid of the volcanic layers, showed corresponding variations over the whole area and were nearly the same as those from Europe, North America, New Zealand and Asia, indicating that South America has undergone climate oscillations of a world wide nature.

The climatic fluctuations are revealed in the struggle between forest and 'steppe'. After the glacial epoch the forest extended from the mountains and reached the coast at the Straits of Magellan, whence it retired rapidly to its present extent. The period of advance is designated the *Melioratum* (improvement) and that of recession the *Peioratum* (deterioration). A dry, windy, post-glacial climate is followed by less windy and more humid conditions between the eruption groups I and II, during which the forest made rapid advances. A short dry period beginning a little before the group II eruptions and ending a little after them is followed by a further humid period lasting well beyond the group III eruptions. A drier period with regression of the forest brings the story up to historical times.

A photo shows the retreating forest margin. Other photos show varves and ash profiles. The limits reached (isohylochrones) by species of *Nothofagus*, *Fuchsia*, *Drimys* and *Philesia* during the three periods are shown on a series of maps. Mention is made of the famous cave of Palli Aike where were found human skeletons associated with those of the primitive horse. These met their death in the ashes of the first eruptions so are approximately 9000-10,000 years old and show that man arrived there immediately after the glacial period. Diagrams show succession in a lake deposit culminating in a convex *Sphagnum* stage, the gradient in the rate of peat accumulation from the sea coast to the mountains and successional stages in the replacement of forest by 'steppe'.

Besides the pollen work, sediments were studied chemically and petrologically, and shore lines of coasts and lakes are discussed. The method is synthetic in that the occurrence of volcanic strata provides synchronous points in the peat deposits while the succession revealed by pollen analyses from the peat layers permits of correlations with a climate-history chronology.

Not only does the work open up new perspectives for the study of Nature in Argentine and Chile, but it is of importance to New Zealand science. This is one of the few regions in our latitude where confirmation might be sought that the major climate oscillations were world wide, thus permitting the application of the northern chronology.

Though the author's headquarters are at Helsinki, in Finland, the paper is in Spanish, and the reviewer is indebted to Dr. J. G. Gibbs, Victoria University College, for a translation, a copy of which may be obtained on loan.

W. F. HARRIS.

29 June 1949.

TIMBER PRESERVATION TESTS WITH *ANOBIUM PUNCTATUM* DE GEER.

By J. M. KELSEY, Entomology Division, Department of Scientific and Industrial Research, Nelson

(*Received for publication, 17th March, 1948*)

Summary

This paper describes a laboratory technique for determining the exact thicknesses through which *Anobium* larvae can tunnel in preserved timber and then survive in untreated wood. In general, larvae would not cross glue lines from untreated to treated wood, but did so in the reverse direction and when timber each side of the glue line was untreated. Two preservatives were tested—one water- and one oil-soluble—each at a concentration of 5 per cent by weight. Results indicated that timbers treated in such a way as to give a preserved outer zone of up to ⅛ in. in thickness, did not constitute an impassable barrier to *Anobium* larvae under the conditions of the experiments. Results indicate the danger arising from cutting or other damage to wood treated by superficial methods.

INTRODUCTION

THIS investigation was undertaken with a view to overcoming the difficulty of determining either visually or by chemical colour reactions just how far preservatives have penetrated into timber. Colour reactions indicate merely that a certain amount of perservative has penetrated as far as the coloured zone, but do not show the exact limits of penetration of smaller amounts of preservative to which these reactions lack sensitivity. It was thought, therefore, that by treating wood veneers of different thicknesses till they were completely penetrated, and then glueing these to untreated timber, it might be possible to determine (a) the exact thickness of preserved zone necessary to prevent *Anobium* larvae crossing from one wooden member to another, and (b) the exact thickness of preserved zone necessary to stop *Anobium* larvae, when they emerge from eggs laid on treated surfaces, from entering the untreated core of timbers treated by superficial methods. This phase of the work was considered to be of utmost importance in that it would provide information as to the relative merits of surface as opposed to pressure treatments.

Considerable confusion arises when overseas literature is summarised, since there is a wide divergence of opinions as to the necessity for setting up the costly plants necessary for pressure treatment of timber. In spite of numerous papers of this nature there is not a great deal of positive information on the subject, but the question obviously is of sufficient importance to justify carrying out tests to determine whether or not it is possible, by incomplete penetration of preservatives, to provide an effective barrier against wood borer and fungus attack.

If a preservative is not repellent to insects the wood at some time may become a site for oviposition by one or more of the wood destroying insects, and since many preservatives must be eaten to be of any use as a control, the larvae emerging from such eggs may be able to penetrate through the zones preserved by superficial methods. It has been shown (1) (2) that *Anobium* larvae, even just after emergence from eggs, can tunnel through ⅛ in. and live for up to 26 weeks in timber which contains

an amount of preservative that would ultimately prove toxic if activities were restricted to the treated zone. Though these two cases involve water-soluble preservatives, it will be seen later in this paper that the same thing applies to some oil-soluble preservatives.

EXPERIMENTAL

The only timber used was sap-wood kahikatea (*Podocarpus dacrydioides* A. Rich) as this timber is known to be readily attacked by *Anobium*.

The timber was milled in August, 1943, and since preservative treatment was carried out on 25th and 26th August, 1944 it was 12 months old at time of treatment. During this period the wood was kept under cover and exposed to maximum sunlight, but was sheltered from rain.

The two following preservatives were used in two series :—

Series I,

a. Pentachlorophenol—5 per cent. by weight
Lighting kerosene- 95 per cent. by weight.

b. Sodium pentachlorophenate—5 per cent. by weight
Water—95 per cent. by weight.

Treatment :

For pentachlorophenol a preliminary 40 minute vacuum followed by the running in of the solution.

For sodium pentachlorophenate a preliminary 40 minute vacuum followed by the running in of the solution ; the blocks were then allowed to remain submerged in the liquid for from 1½-2½ hours.

INDICATORS.

To give some idea as to the extent of penetration, a 10 per cent. by weight solution of silver nitrate in water was used for both preservatives. The oil carrier for pentachlorophenol masked the colour reaction and it was not till the kerosene had to some extent evaporated that this test could be used. The penetration of the oil-soluble preservative was so rapid with the above treatment that no dipping period was necessary after running the liquid into the block compartment.

There was a marked difference between the oil- and water-soluble preservatives as regards speed of penetration even with the same vacuum times. With a two hour dip following the vacuum phase of treatment it was still found that penetration of the water-soluble type in the largest blocks was incomplete, and though a 2½ hour dip appeared to give the desired results there was still an element of uncertainty ; it was therefore decided to discard all the blocks treated by this method. This decision was influenced too, by the deposition of pentachlorophenol crystals on the wood surface as the blocks dried out.

The second series involved the same two preservatives with an altered formula for the pentachlorophenol as follows :—

Series II,

a. Pentachlorophenol—5 per cent. by weight
Linseed oil—3 per cent. by weight
Lighting kerosene—92 per cent. by weight

b. Sodium pentachlorophenate—5 per cent. by weight
Water—95 per cent. by weight.

TREATMENT.

This consisted in each case of a dip treatment only. It was found that the pentachlorophenol completely penetrated the largest blocks within 12 hours, whereas the same size blocks required 60 hours with the sodium pentachlorophenate. The exact times required to penetrate completely blocks of different sizes were not recorded. When 10 per cent. silver nitrate indicated complete penetration in the largest blocks it was presumed that the smaller blocks also were completely penetrated. This was borne out by tests at the conclusion of the experiments. The 3 per cent. of linseed oil effectively prevented surface crystallisation of pentachlorophenol, but hindered colour reactions till drying out had proceeded for two months.

Anobium larvae were split from infested rimu, matai, kahikatea, and sap-wood kauri, kept in petri dishes for three days to eliminate weak or injured larvae, and then transfrered to holes drilled in kahikatea from the same boards as the test pieces. To avoid any difference due to different wood species, the larvae were left in these kahikatea blocks for four months. These blocks were then split to recover larvae for transfer to holes drilled in the test pieces after the larvae had again been left for three days prior to placement in experimental samples.

Blocks were glued together in the form of " sandwiches " for larvae transfer tests (Type A, Fig. 1): and in the form of cubes for egg-laying tests (Type B, Fig. 1).

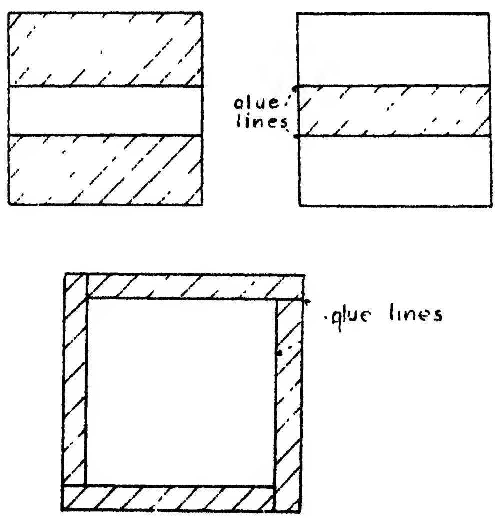

FIG. 1.—Diagrams showing relationship of treated to untreated areas of blocks.
Shaded zone = treated.
Unshaded zone = untreated.

Since the object of the tests was to determine through what thickness of treated wood the emerging larvae could tunnel, exposed ends of the egg-laying samples were treated with paints, enamels, or sodium silicate to prevent oviposition on end grain. The treated surfaces were roughened to make crevices in which eggs could be laid.

GLUES.

Unpreserved glues were used for the main experiments, but a subsidiary test using a casein glue treated with copper sulphate, lime and sodium silicate was also carried out. Carpenters glue made from casein, gum arabic, horn, hooves, etc., and the flour paste used by paperhangers, were found to make good seals between treated and untreated pieces of timber ; the last of these proved the best. After glueing, the blocks were subjected to pressure in a bookbinders' hand-operated press until the glue was dry.

Seven replications were used for each phase of the experiments, and the final dimensions of blocks were 2 in. by 1 in. by 1 in. for the "sandwiches" used in larva-transfer, and 1 in. by 1 in. by 1 in. for egg-laying tests.

Cages were of the prell type described previously (3) ond one block was placed in each.

Drilling of holes in samples for larva-transfer tests was carried out prior to glueing and holes were made ⅜ in. deep in the edges of blocks by means of a power-driven drill. Any blocks showing broken side surfaces due to drilling were discarded.

In egg-laying experiments five female and five male beetles were used in each cage. In larva tests 12 larvae were used in each of the sodium pentachlorophenate-treated blocks and their untreated controls, and 16 larvae to each pentachlorophenol-treated sample and their controls, and six in the untreated blocks using treated casein glue. It was found that best results were obtained by using the largest larvae that could enter the drill holes. If larvae were too small they appeared to have difficulty in tunnelling into the wood from the drill hole.

RESULTS

Table I gives results of experiments commenced on 13th November, 1944, with the larva transfer tests and these blocks were split up on 15th May, 1945. Larvae were placed in the centre of the three layers in each case.

It will be noted that even in untreated control tests the *Anobium* larvae preferred to remain in the layers in which they were placed rather than cross the glue lines, though this was less marked when flour paste was used to glue blocks.

When larvae were placed in the untreated core with treated layers outside, no larvae crossed the line of glue into treated wood, though with the flour paste series some larvae had commenced to excavate the surface of the treated blocks.

When larvae were placed in layers treated with sodium pentachlorophenate and using protein glue, only four larvae had crossed the glue line, and of these only one was alive and apparently healthy ; two of them had pupated and transformed to almost mature adults before dying. Larvae surviving from those placed in pentachlorophenol-treated layers had all crossed the glue line into untreated zones, and all appeared to be healthy.

The treated casein glue was effective in preventing larvae from passing between untreated layers, but very extensive damage was caused to the zones in which larvae had been placed.

Untreated layers, whether in control or preservative tests, were mere shells, as larvae had completely destroyed these zones.

TABLE I.

Preservative.	Cage No	Larvae placed in.	Thickness of infested layer In.	Live larvae recovered	Glue.	Remarks.
Sodium pentachlorophenate	1	untreated zone	$\frac{1}{16}$	2	Protein	None through glue
	2		$\frac{1}{16}$	2		,,
	3		$\frac{1}{16}$	2		,,
	4		$\frac{1}{8}$	4		,,
	5		$\frac{1}{8}$	5		,,
	6		$\frac{1}{8}$	0		,,
	7		$\frac{1}{4}$	2		,,
Sodium pentachlorophenate	8	treated zone	$\frac{1}{16}$	0	Protein	2 dead adults through glue
	9		$\frac{1}{16}$	1		2 through glue : 1 alive
	10		$\frac{1}{16}$	0		None through glue
	11		$\frac{1}{8}$	0		,,
	12		$\frac{1}{8}$	0		,,
	13		$\frac{1}{8}$	0		,,
	14		$\frac{1}{4}$	0		,,
Control	a		$\frac{1}{16}$	10	,,	0 through glue
	b		$\frac{1}{8}$	7		,,
Pentachlorophenol	15	untreated zone	$\frac{1}{16}$	12	Flour	0 through glue
	16		$\frac{1}{16}$	5		,,
	17		$\frac{1}{16}$	7		,,
	18		$\frac{1}{8}$	11		,,
	19		$\frac{1}{8}$	12		,,
	20		$\frac{1}{8}$	4		,,
	21		$\frac{1}{4}$	8		,,
Pentachlorophenol	22	treated zone	$\frac{1}{16}$	9	Flour	All through glue
	23		$\frac{1}{16}$	11		,,
	24		$\frac{1}{16}$	5		,,
	25		$\frac{1}{8}$	11		,,
	26		$\frac{1}{8}$	4		,,
	27		$\frac{1}{8}$	6		,,
	28		$\frac{1}{4}$	2		,,
Control	c		$\frac{1}{8}$	6	,,	2 through glue
	d		$\frac{1}{8}$	14		7 ,,
	e		$\frac{1}{8}$	11		6 ,,
	f		$\frac{1}{8}$	8		4 ,,
Treated casein glue	29	untreated zones	$\frac{1}{8}$	4		0 through glue
	30		$\frac{1}{8}$	2		1 ,,
	31		$\frac{1}{8}$	2		1 ,,

It was unfortunate that these experiments could not have been carried out as planned originally, since there is no direct comparison between the two preservatives due to the fact that the two adhesives were different in each series. The protein glue was definitely inferior to the flour paste.

Table II gives results of egg-laying tests using blocks of Type B where an untreated core was surrounded by $\frac{1}{16}$ in. thick layers of treated wood. Veneers were treated in July, 1944, and subjected to oviposition tests during the 1946-47 *Anobium* flight season, and examined in January, 1948. Flour adhesive was used for all blocks.

TABLE II.

Preservative.	Block No.	Number of eggs laid on blocks.	Number of larvae tunnelling in.	Live larvae recovered.
Sodium pentachlorophenate	1	15	10	3
	2	4	2	0
	3	0	0	0
	4	7	3	1
	5	23	19	2
	6	11	2	0
	7	9	5	1
Controls	a	85	71	54
	b	165	137	81
	c	60	48	33
Pentachlorophenol	8	27	14	4
	9	17	9	1
	10	8	0	0
	11	3	0	0
	12	29	19	7
	13	16	13	4
	14	5	2	1
Controls	d	180	151	101
	e	29	28	19
	f	215	184	87

The controls were blocks of untreated wood of the same dimensions as the treated samples. Using the same adhesive as with the treated blocks, it was found that over 62 per cent. of the live larvae in the controls had crossed the glue line, due possibly to the fact that the $\frac{1}{16}$ in. outer veneers had been completely hollowed out by the larvae.

In the case of the treated samples the results indicated that the preservatives tended to reduce oviposition by *Anobium*, but did not entirely inhibit it.

The figures given in Table II are derived from eggs actually laid on treated surfaces, but in addition, varying numbers of eggs had been laid on the paint seals over the end grain of the untreated cores. Any larvae tunnelling into the wood from such eggs were counted as surviving, and so were deducted from the total number of larvae found in central untreated zones. The possibility of error here is not great since a binocular microscope was used to determine whether or not eggs had hatched; the blocks were then carefully split by means of a heavy knife and examined with the microscope.

The paint seals did not give a smooth glossy seal to the end grain of blocks and this is apparently the reason for their failure to prevent attack by the larvae, as it was only on the rougher surfaces that eggs were laid. Even though paint coverage was complete on rough surfaces, the larvae were able to tunnel through from eggs deposited in such areas.

Table III gives results of egg-laying tests with Type B blocks using outer treated layers $\frac{1}{4}$ in. thick.

Here again eggs had been laid on the paint-sealed ends of untreated cores, and many larvae were alive when the blocks were split up. In no case, however, had larvae, emerging from eggs laid on treated surfaces, been able to tunnel through the full $\frac{1}{4}$ in. thickness of timber into the untreated cores. Once with sodium pentachlorophenate and on two

TABLE III.

Preservative.	Block No.	Number of eggs laid on blocks.	Number of larvae tunnelling in.	Live larvae recovered.
Sodium pentachloro-phenate	15	0	0	0
	16	0	0	0
	17	0	0	0
	18	13	10	0
	19	37	31	0
	20	6	4	0
	21	4	2	0
Controls	g	111	105	65
	h	73	60	51
	i	49	49	42
Pentachloro-phenol	22	5	4	0
	23	1	1	0
	24	1	0	0
	25	1	0	0
	26	41	37	0
	27	3	2	0
	28	19	14	0
Controls	j	166	161	93
	k	47	36	31
	l	153	139	129

occasions with pentachlorophenol, larvae had made tunnels $\frac{1}{8}$ in., $\frac{3}{32}$ in. and $\frac{1}{8}$ in. long respectively before dying. However, they had not penetrated as far as the glue line between treated and untreated zones. Nevertheless, it seems, that it is not impossible for *Anobium* larvae to penetrate through a treated zone of up to $\frac{1}{8}$ in. thickness ; whether or not they could then survive in untreated wood below the treated zone is not indicated by the above tests.

In untreated controls 226 larvae, or just over 55 per cent. of those recovered alive had tunnelled through the glue lines.

CONCLUSIONS

In general it can be stated that the above " sandwich " technique for testing timber preservatives is effective only when flour paste is used as the adhesive. Results of this phase of the tests showed that actively feeding larvae are unlikely to enter treated timber from untreated wood ; this information has a bearing on commercial treatments of infested buildings. An important point to bear in mind, however, is that mature larvae may tunnel through a treated zone for $\frac{3}{4}$ in. or more without actually eating any wood ; if this is not recognised the value of a preservative might easily be overlooked.

Measurements of actual tunnels beyond drill holes showed from larva transfer tests that *Anobium* larvae can tunnel for a distance of $\frac{11}{16}$ in. in timber treated with 5 per cent. concentrations of both the above preservatives, and from egg-laying tests for a distance of $\frac{1}{8}$ in. The larva transfer results are significant only in so far as they show that larvae are able to live for a considerable time and tunnel as far as $\frac{11}{16}$ in. in timber treated with preservatives at concentrations that will ultimately prove toxic ; this has a direct bearing on interpretation of results with preservatives used to control infestations in buildings. This transfer technique does not give information on treatment before timber becomes

infested, except that larvae would not pass from untreated wood into wood treated with either of the preservatives.

The egg-laying technique gives information as to what is likely to occur with superficial pre-treatment of timbers, involving such processes as short-period dipping or surface spraying. It also provides a means of assessing the effectiveness of commercial methods for borer control.

Dip or other treatments that give outer preserved zones of up to ⅛ in. in thickness will,—with the two preservatives tested here—materially reduce the chances of infestation by *Anobium*, but will not completely prevent infestation. In practice the writer thinks that it is unlikely that timber treated thoroughly with the above two preservatives will be attacked by *Anobium*, at least within about five years of treatment, since it must be remembered that in these laboratory tests the beetles were confined in small cages with single blocks, and with nowhere else to deposit eggs. This, of course, would not arise under normal commercial applications. Nevertheless, eggs were laid on blocks treated with both water- and oil-soluble preservatives, and even though only three larvae out of a total of 202 that entered the treated wood tunnelled for distances exceeding $\frac{1}{16}$ in., the fact remains that once the surface zone of treated wood is broken by even one or two emerging adult beetles, this will permit access by way of these exit holes, to the untreated wood beneath.

It was obvious that the two preservatives or residual effects of the solvents, exercised a certain degree of repellancy so far as oviposition was concerned. The tests did not, however, reveal wether this repellancy was due to volatile or contact effects; if it was due to the former the question of permanence of the preservatives arises, since volatility means that either the carriers or preservatives themselves are losing something to the surrounding atmosphere.

A further point brought out by the egg-laying trials was that eggs were laid on the paint seals covering untreated wood, and larvae were able to tunnel through the paint and survive in the timber beneath. This point illustrates the danger arising when timber is pretreated by dipping, spraying or other methods that give a superficial zone of preserved wood. If, after treatment, such timber has its surface broken in any way, such as by sawing, nailing or lapping of joints, the untreated wood in the centre would be exposed. There would then be nothing to prevent oviposition on such areas; indeed it is usually found that angles, joins and end grains are preferred by such wood-boring insects.

ACKNOWLEDGMENTS

The writer is indebted to Miss R. W. Denne, Plant Diseases Division, Auckland, for carrying out the preservation work involving vacuum treatment of some of the wood samples.

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NOTE ON THE COLORIMETRIC DETERMINATION OF ZINC IN PLANT MATERIAL

By J. WATSON, Cawthron Institute, Nelson, New Zealand

(Received for publication, 8th September, 1949)

Summary

The method of Cholak, Hubbard and Burkey (1) for the colorimetric estimation of zinc in plant material has been tested on samples of apple leaves. The method with certain minor modifications, has given results which agree closely with determinations made by the polarographic method of zinc estimation

IN view of possible zinc deficiencies occurring on certain orchard soils in the Nelson district the determination of the zinc content of apple leaves and other plant samples was undertaken.

The colorimetric method described by Cholak, Hubbard, and Burkey (1) based on the red colour produced by zinc and di-beta-naphthyl-thiocarbazone was examined with a view to its adoption for zinc estimations at the Cawthron Institute.

Chloroform solutions of di-beta-naphthyl-thiocarbazone extract a number of metals and therefore all except zinc must be prevented from forming coloured complexes. The addition of sodium di-ethyl dithiocarbamate to the aqueous phase prevents the formation of a number of these complexes without affecting the extraction of the zinc. Of the metals which react with carbamate, copper, nickel, cobalt, and bismuth when present in large amounts), give chloroform-soluble coloured complexes which affect the final estimation unless they are removed. The carbamate complexes of nickel, cobalt and copper, are insoluble in 0.2N hydrochloric acid and therefore they remain in the chloroform phase when the latter is treated with weak acid. The bismuth carbamate may enter the acid phase, particularly when large amounts of bismuth are present. When less than 100 μg. of bismuth are present a coloured chloroform-soluble carbamate complex is not formed.

Since the final colorimetric estimation of zinc is carried out by adding sufficient ammonia to the acid phase and re-extracting with di-beta-naphthyl-thiocarbazone interference by the small amounts of bismuth, which may have been carried along with the zinc, is inhibited by the addition of more carbamate at this point.

The main difficulty encountered in the estimation was the introduction of zinc from outside sources. All glassware had to be boiled in dilute nitric acid, and wooden stands were used to hold the separatory funnels.

REAGENTS FOR THE ESTIMATION OF ZINC

Zinc-free, distilled water.
Zinc-free, ammonium hydroxide.
Zinc free, hydrochloric acid.
Forty per cent ammonium citrate solution.
Carbamate solution.
Di-beta-naphthyl-thiocarbazone.

The reagents were purified by the methods and used at the concentrations recommended by Cholak, Hubbard and Burkey (1) except for the di-beta-naphthyl-thiocarbazone, which was used at half their concentration and was made up daily by dissolving 25 mg. in 250 ml. of chloroform.

METHOD OF ESTIMATING ZINC IN APPLE LEAVES

From 0.5 - 1.0 g. of dried finely ground sample was weighed into an 8 in by 1 in. pyrex test-tube; two or three small pieces of zinc-free quartz pebble were added, then 5 ml. of a mixture of sulphuric and perchloric acids. (This consists of 1 ml. of 60 per cent perchloric acid, 1 ml. concentrated sulphuric acid and 3 ml. zinc-free water.) One millilitre of nitric acid was then added and the open tube placed on a digestion rack over a small flame. The mixture was heated gently until boiling, then a further millilitre of nitric acid was added slowly. When the digestion was proceeding quietly the burners were turned up. More nitric acid was added when the digest began to blacken and give off white fumes. After the digest was clear, heating was continued for another 15 minutes, the volume then being about 1 ml. When cool, the digest was transferred to a 150 ml. separatory funnel; to this was added 30 ml. of 20 per cent ammonium citrate solution and four drops of 0.1 per cent aqueous thymal blue followed by zinc-free ammonium hydroxide (sp. gr. 0.9) until pH 9.5 was reached.

Four millilitres of carbamate solution were added and sufficient zinc-free water to make up to 100 ml.; the solution was then shaken for one minute with 10 ml. of the di-beta-naphthyl-thiocarbazone reagent. The chloroform layer was drained into a second funnel; a further 5 ml. of the reagent were added and the solution again shaken. This portion, which should retain its original blue-green colour, was drained into the second funnel. If it shows any red coloration too much zinc is present and an aliquot of the digested sample must be taken. The combined chloroform extracts were washed with 50 ml. of zinc-free water and drained into another funnel. Any reagent entrained in the aqueous phase was removed by shaking it with one or two millilitres of chloroform which were added to the washed chloroform phase. The chloroform solution was then shaken with 50 ml. of 0.2N hydrochloric acid and the chloroform layer was run into a residue bottle. Entrained reagent was removed from the acid by shaking with chloroform.

In another separatory funnel 45 ml. of ammonium hydroxide (50 ml. of sp. gr. 0.9 ammonium hydroxide diluted to 1,000 ml. with zinc-free water) and 1 ml. of carbamate were shaken with 5 ml. of di-beta-naphthyl-thiocarbazone reagent. The reagent extract was discarded and the ammonium hydroxide solution was washed once with 5 ml. of chloroform which was discarded. This solution was added to the 0.2N hydrochloric acid extract. Any chloroform kept in was drained off before shaking for one minute with 10 ml. of the reagent.

For the estimation, 2.5 ml. of the chloroform layer were diluted to 25 ml. with pure chloroform. The red colour was measured in a Lovibond Tintometer using a one inch cell.

To obtain a standard graph, known amounts of a standard zinc sulphate solution were added to 50 ml. of 0.2N hydrochloric acid; 45 ml. of treated ammonium hydroxide were then added and the solution shaken for one minute with 10 ml. of the reagent. 2.5 ml. of the chloroform layer were diluted to 25 ml. with chloroform, and the red units read in the Tintometer. An almost straight line graph was obtained for amounts of zinc ranging from 10-40 μg.

The results obtained bv the above method agreed favourably with those obtained by the Dominion Laboratory, Wellington, using the polarograph, as can be seen in Table I.

TABLE I. ZINC CONTENT OF APPLE LEAVES

Lab. No.	Colorimetric Method (p.p.m.)	Polarograph Method (p.p.m.)
2149	21.4	21.2
2153	28	31
2157	18	19
2161	16	15
2178	21	22
2179	23	19
2264	24	20

DISCUSSION

Three minor modifications have been introduced into the method outlined by Cholak, Hubbard and Burkey (1) for the colorimetric estimation of zinc. These modifications are as follows:—

(1) The plant samples for zinc determinations were subjected solely to wet digestion with sulphuric and perchloric acids and not to the combination of wet digestion and ashing recommended bv Cholak, Hubbard and Burkey.

(2) The di-beta-naphthyl-thiocarbazone reagent was made up fresh daily, using only one half of the concentration recommended by the authors of the original paper. This procedure was adopted because refrigeration was not available for the storage of the reagent.

(3) For the final estimation of zinc, 2.5 ml. of the extract were diluted to 25 ml. instead of the 5 ml. to 100 ml. specified in the original paper.

With the adoption of these modifications, the method gave results which agreed closely with those obtained by the polarographic method for zinc determination.

Experience in the use of the method for the colorimetric estimation of zinc showed the great importance of removing casual sources of zinc contamination. Not only must all reagents be carefully purified but special care must be taken to use glassware which is free from zinc.

It was found necessary to grind plant samples in a porcelain mortar or in a handmill free from zinc in its construction.

Another point of importance in securing accurate zinc determinations is the pH value of the solution prior to the initial extraction with the di-beta-naphthyl-thiocarbazone reagent. The pH of the solution must be 9.5 or the zinc will not be extracted into the chloroform layer. For the complete extraction of zinc by the dilute hydrochloric acid from the chloroform phase it is important to shake for at least one minute.

ACKNOWLEDGMENT

The author desires to thank the Director of the Dominion Laboratory, Wellington, for arranging for the polarographic determinations of zinc quoted in Table I.

REFERENCE

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REVIEW

IONOSPHERE RADIO PROPAGATION

U.S. National Bureau of Standards Circular 462. Obtainable from Superintendent of Documents. Price, 1$.

This book provides a well balanced treatment of the factors involved in radio-wave propagation A large section is devoted to the calculation of field strengths, lowest required radiated power, noise, etc., giving one an excellent perspective of their significance as compared with the more commonly treated frequency predictions. Nothing has been sacrificed however in the treatment of the latter. The structure of the ionosphere, its long and short term variations are discussed in a clear and well illustrated manner. One is gently, if rapidly, introduced into electromagnetic wave theory in the second chapter but on the whole the text makes easy reading. The various nomographs and diagrams are very clear and can be readily interpreted with the exception of some examples of ionosphere records which leave much to be desired. One gains the impression that the quality of the paper, the type, and the subject treatment, are worthy of something more than a flimsy cardboard binding.

REVIEW:

Natural Philosophy through the Eighteenth Century, and Allied Topics. (Commemoration Number to mark the 150th Anniversary of the foundation of the Philosophical Magazine.) Taylor and Francis Ltd., 18 Red Lion Court, London, E.C.4. 1948. Pp. vii+164. 15s.

The Philosophical Magazine has existed as an independent journal since 1798, and its contributors include many of the most illustrious names in the history of the physical sciences. The present number, commemorating its 150th anniversary, contains a short history of the magazine itself, followed by articles on the eighteenth century development of the following subjects:—Astronomy, Physics, Chemistry, Mathematics, Engineering and Invention, Scientific Instruments, The Scientific Periodical, Scientific Societies, and Teaching of the Physical Sciences, each written by a different authority. It is readable by anyone interested in the history of 'Natural Philosophy,' and enlivened here and there by personal details which reflect the romantic aspects of many scientific developments in the eighteenth century, the 'heroic age' of the physical sciences. To quote from Boswell, "Chymistry was always an interesting pursuit with Dr. Johnson. Whilst he was in Wiltshire he attended some experiments that were made by a physician at Salisbury, on the new kinds of air. In the course of the experiments frequent mention being made of Dr. Priestley, Dr. Johnson knit his brows, and in a stern manner enquired, 'Why do we hear so much of Dr. Priestley?' He was very properly answered, 'Sir, because we are indebted to him for these important discoveries.' On this Dr. Johnson appeared well content; and replied, 'Well, well, I believe we are; and let every man have the honour he has merited'.

It is more practicable to pay such honour to individuals of the small band of scientific heroes of those times than it is to the army of scientific workers today. Many of them had but little education and could command only the crudest facilities for scientific experiment. Professor Partington quotes Hoefer's remark on Scheele, 'avec de petites ressources, il fit de grandes choses,' and this could apply to many of the scientists and engineers of the century.

Apart from the personal aspects, the number gives a compact and readable account of the development of scientific thought and discovery during the period; the ancillary subjects, engineering and instruments, educational methods, periodicals and societies, form a valuable background which is often not given in scientific histories. It can be recommended for the library of any natural philosopher.

W. M. J.

A METHOD FOR THE ANALYSIS OF MIXTURES OF INORGANIC SULPHUR COMPOUNDS

By J. L. MANGAN, Plant Chemistry Laboratory, Department of Scientific and Industrial Research, Palmerston North

(*Received for publication, 21st March, 1948*)

Summary

1. A method is described for the separation and estimation, in mixtures, of dithionate, polythionate, sulphate, thiosulphate, sulphite and sulphide in one aliquot of a solution.
2. The method depends on the properties of the lead salts, and the solubilities of lead thiosulphate, sulphate and sulphite have been determined in solutions of ammonium acetate at concentrations 0-5 M. The effects of change in pH and temperature have also been observed.
3 The method has been applied to plant extracts and has been found satisfactory although the accuracy of results is of a lower degree than that obtained in pure solutions

INTRODUCTION

IN the literature, methods recorded for the analysis of mixtures of inorganic sulphur compounds are cumbersome, and make use of a number of aliquots in which specific reactions are carried out for each component (1) (2). There is no attempt made in any method to separate the compounds, and the methods apply only to pure solutions and are not reliable for plant extracts.

In work on the storage of dehydrated vegetables (3) (4), it was found that the loss of sulphur dioxide on storage was due not only to direct oxidation to sulphate, but also to some more complicated process in which intermediates, unstable in hot dilute acid solution, were formed. To investigate this further, a method for the estimation of inorganic sulphur compounds in vegetable extracts became desirable. The method described below uses only one sample of the solution, and upon this can be carried out estimations of dithionate, polythionate (includes tri-, tetra- and penta- thionates), thiosulphate, sulphate, sulphite and sulphide. The method depends on the solubilities of the lead salts, and the above compounds can be separated into four groups.

Group I consists of dithionate and the higher polythionates since their lead salts are freely soluble in water and aqueous alcohol.

Group II consists of lead sulphate and thiosulphate which, although slightly soluble in water, are quite insoluble in 65 per cent. V/V alcohol-water.

Group III consists of lead sulphite, which is insoluble in water and aqueous alcohol but soluble in sodium hydroxide solution.

Group IV consists of lead sulphide which is insoluble in sodium hydroxide solution.

Group II is separated from Groups III and IV by its preferential solubility in ammonium acetate solution, lead sulphate and thiosulphate being very soluble, while lead sulphite is only slightly soluble and lead sulphide insoluble.

The groups thus separated are analysed for their components. In group I polythionate is determined in the presence of dithionate by its oxidation to sulphate under alkaline conditions. After determination of the sulphate formed, dithionate, which is quite stable to oxidation is hydrolysed by the reaction

$$H_2S_2O_6 + H_2O \xrightarrow{\text{acid}} H_2SO_4 + H_2SO_3$$

and the sulphur dioxide determined by the Monier-Williams method (5) for sulphite. In group II thiosulphate is determined by titration with iodine, and sulphate then determined by the barium chloride method. Sulphite in group III is estimated by iodine titration. Sulphide in group IV is oxidized to sulphur by excess standard iodine in acid solution, and the excess iodine remaining is determined by thiosulphate titration.

No information was to be found in the literature on the solubility of lead thiosulphate and lead sulphite in ammonium acetate solutions, and little on the solubility of lead sulphate. The first step in the investigation was therefore a determination of their solubilities, taking into consideration factors likely to assist in the separation of the groups.

SOLUBILITIES OF LEAD THIOSULPHATE, SULPHITE AND SULPHATE IN AMMONIUM ACETATE SOLUTIONS OF DIFFERENT CONCENTRATIONS

Lead thiosulphate :

A large quantity of lead thiosulphate was precipitated and centrifuged. The supernatant liquid was poured off and the solid suspended in water and centrifuged again. This washing was repeated. The thiosulphate was obtained as a hardpacked damp solid. Ammonium acetate solutions at pH 6.0 were made to concentrations 0.5, 1.0, 1.5, 2, 3, 4 and 5 molar.

In 20 ml. of each of the ammonium acetate solutions in centrifuge tubes an excess of the damp lead thiosulphate was suspended. After being stoppered and thoroughly shaken, the tubes were centrifuged, the supernatant solution discarded and the tubes well drained. The washed lead thiosulphate samples were then suspended again in their appropriate ammonium acetate solutions and kept in the thermostat at 20°C. for 2 to 3 hours with shaking. The suspended solid was allowed to settle and the saturated solution filtered rapidly. Five millilitre samples were taken, diluted to about 50 ml., and after acidifying to pH 5 with hydrochloric acid, were titrated with 0.02N. iodine using starch indicator. The figures were corrected for a blank titration.

Lead Sulphite :

The solubility of lead sulphite in ammonium acetate solutions of different concentrations was determined as for thiosulphate. In this case to prevent oxidation 5 per cent. sucrose was added to the ammonium acetate solutions. This was necessary since any sulphate formed would dissolve in the ammonium acetate and depress the solubility of the lead sulphite. The lead sulphite was precipitated and washed thoroughly with 5 per cent. sucrose solution, and finally washed with the appropriate ammonium acetate solutions before the solubility was determined. Five ml. of the solution saturated with lead sulphite was titrated with 0.02N. iodine at pH 5 as for thiosulphate.

Lead Sulphate :

Pure dry lead sulphate was suspended in solutions of ammonium acetate of different concentrations and the suspension kept in the thermostat at 20°c. for 3 to 4 hours with shaking. The solutions were allowed to settle, filtered rapidly and 10 ml. aliquots taken. Excess concentrated sulphuric acid was added and the acetic acid boiled off. After cooling, sufficient water was added to give a solution containing 20 per cent. sulphuric acid. The lead sulphate was filtered on to a prepared Gooch crucible, washed with 20 per cent. sulphuric acid saturated with lead sulphate and finally with 70 per cent. aqueous alcohol, dried at 110°c. and weighed. A check was made by extracting the lead sulphate from the crucible with hot ammonium acetate solution and reweighing.

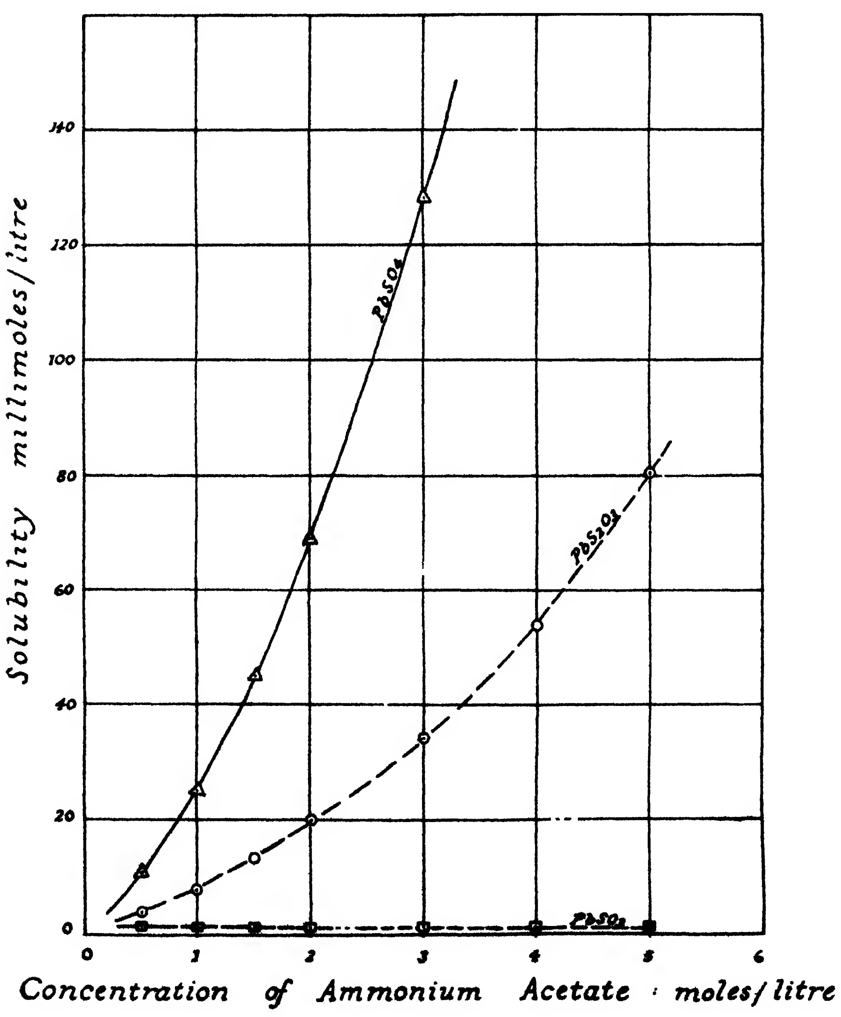

FIG. 1

TABLE I. SOLUBILITY OF LEAD THIOSULPHATE, SULPHITE AND SULPHATE IN AMMONIUM ACETATE SOLUTIONS AT 20°C.

Ammonium Acetate moles/litre.	Solubility PbS_2O_3 millimoles/litre	Solubility $PbSO_3$ millimoles/litre.	Solubility $PbSO_4$ millimoles/litre.
0.5	3.86	1.80	10.75
1.0	8.00	1.20	25.33
1.5	13.24	1.40	45.25
2.0	19.98	1.40	69.15
3.0	34.12	1.40	128.0
4.0	54.00	1.00	257.7
5.0	80.24	1.60	385

The solubilities of the three compunds are given in Table I, and for convenience plotted on a common scale against the concentration of ammonium acetate in Fig. 1. It is seen that the solubility of the thiosulphate and the sulphate increases very rapidly with increasing concentration, but that the solubility of the sulphite is practically unchanged.

THE EFFECT OF pH ON SOLUBILITY OF THE LEAD SALTS IN AMMONIUM ACETATE SOLUTIONS

Molar solutions of ammonium acetate at different pH values were prepared as follows: · 50 ml. portions of 2N. acetic acid were titrated with .880 ammonia solution to approximately the required pH. The solution was then made to 100 ml. with water and the pH accurately determined with the glass electrode. The solubilities of lead thiosulphate and sulphite were determined in these solutions as described previously. The solubilities are tabulated in Table II.

TABLE II EFFECT OF pH ON SOLUBILITY IN MOLAR AMMONIUM ACETATE AT 20°C.

pH.	PbS_2O_3 : millimoles/litre.	pH	$PbSO_3$: millimoles/litre.
4.58	3.26	4.8	1.04
4.88	4.64	5.1	0.86
5.26	6.20	5.6	0.72
5.87	7.92	5.9	0.56
6.80	8.84	6.1	0.44
8.60	13.10	7.9	0.36
8.98	11.86	9.0	0.74
9.17	8.32		
9.35	10.76		

It is seen from Fig. 2 below that although the solubility of lead sulphite decreases to a minimum in the pH range 6 to 8, that of lead thiosulphate rises in a smooth curve to approximately pH 6.5 to 7.0, but beyond this point, which coincides with the breakdown of the buffering effect of ammonium acetate, the figures are high but very irregular. A pH beyond 7 would be undesirable, however, because of liability to oxidation of the sulphite, and in practice a solution of pH 6.0 to 6.5 was used. No points were obtained in the dotted portion of the lead sulphite graph due to the very rapid changes in pH of the ammonium acetate in this region.

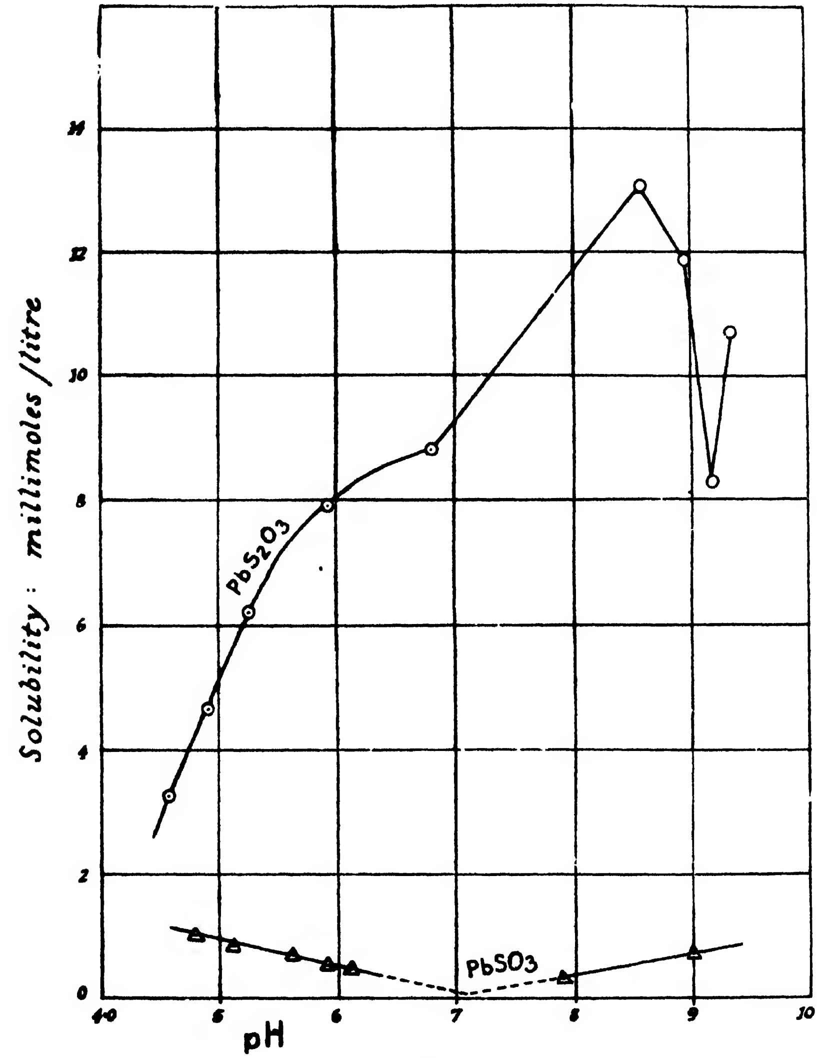

FIG. 2

THE EFFECT OF TEMPERATURE ON SOLUBILITY

The solubilities in molar ammonium acetate at pH 6 were determined, as before, at various temperatures. The results are shown in Table III. A rise in temperature produces a very marked increase in the solubility of lead thiosulphate, but only slightly affects that of the sulphite.

TABLE III. EFFECT OF TEMPERATURE ON SOLUBILITY IN MOLAR AMMONIUM ACETATE AT pH 6.0

Temp. (°c.)	PbS_2O_3 : millimoles/litre.	Temp. (°c.)	$PbSO_3$: millimoles/litre.
0	5.60	0	1.20
19	8.40	15	1.35
42	13.80	42	1.70
56	18.20	56	1.40

The above results show that by suitably choosing the concentration, pH, and temperature of the ammonium acetate solution, there should be little difficulty in effecting a separation of lead sulphite from the sulphate and thiosulphate.

The solubility of lead sulphite, although relatively low, is too high when small amounts of sulphite are to be determined, but it is possible by the addition of 0.5 per cent. lead acetate to the ammonium acetate solution, to reduce the solubility of the sulphite to zero without retarding seriously the solubility of the sulphate and thiosulphate.

Although the solubility data indicated that the method would present no difficulties, a number of problems had to be overcome. Thus when the concentration of sulphur compounds was low, the lead salts remained in the colloidal state and could not be precipitated, thus necessitating the use of an inert carrier. A carrier was also helpful when the precipitate was small and thus difficult to handle. The use of phosphate gave a flocculent, easily handled precipitate, but it was found that this prevented complete extraction of thiosulphate and sulphate with ammonium acetate. The use of citrate with the phosphate gave a good carrier, the lead citrate being soluble and the lead phosphate insoluble in ammonium acetate solution. By suitably adjusting the proportion of citrate to phosphate, complete separation of the two groups could be obtained, but this applied only to that particular solution and did not apply to others. The deciding factor was the ratio of total lead salts soluble to the total amount insoluble in the ammonium acetate. Thus even if no carrier were used, a quantitative separation of thiosulphate and sulphite was possible only if the relative amount of sulphite was small, and when the proportion of sulphite was increased, less and less thiosulphate was extracted. For consistent results it was essential to use a carrier soluble in ammonium acetate. Citrate and tartrate, however, were unsuitable since the solubility of lead sulphite was considerably increased in their presence. Lead chloride was found to be the most suitable carrier. The use of a carrier soluble in ammonium acetate has the added advantage that the concentration of lead ions required to decrease the solubility of lead sulphite is automatically assured. The use of such a carrier, however, meant that sulphite and sulphide had to be handled as a small precipitate, but since this then seemed to be in a flocculent state, no difficulty was experienced in handling amounts of sulphite as small as 0.02 milliequivs in 50 ml.

REAGENTS

Lead Acetate:

20 g. pure lead acetate is dissolved in 65 ml. water with warming, and the volume made to 200 ml. with alcohol.

Ammonium Acetate:

286 ml. glacial acetic acid are diluted with about an equal volume of water and .880 ammonia added dropwise from a dropping funnel until the pH is approximately 6. Bromthymol blue can be used as indicator and ammonia added until a green colour is obtained. If excess ammonia is added the excess may be boiled off. The solution is made up to 1 litre and is approximately 5 molar.

Benzidine Reagent:

1.6 g. benzidine is added to 20 ml. of N.HCl and 45 ml. of water added. The solution is warmed to dissolve the benzidine and the volume then made up to 200 ml. with alcohol.

PROCEDURE

An aliquot of the approximately neutral solution to be analysed is pipetted into a suitably sized centrifuge tube, and two volumes of alcohol added. 0.5 ml. of 10 per cent. sodium chloride solution is added and the solution thoroughly mixed. An excess of the lead acetate reagent is added and the tubes centrifuged at 2,000 r.p.m. for 15 minutes. A drop of lead acetate reagent is added to verify that precipitation is complete. The supernatant solution is carefully poured off and the solid suspended again in aqueous alcohol (2 vols. aclohol to 1 vol. water) using a glass rod with rubber policemen in order to obtain a smooth suspension free from lumps. The tubes are spun again and the washings added to the first supernatant to make up group I.

The insoluble lead salts are then suspended in 10 ml. of ammonium acetate reagent, and diluted to about 50 ml. with distilled water containing 5 per cent. sucrose or glycerol to prevent oxidation of sulphite. 2 or 3 drops of iso-butyl alcohol are added to prevent troublesome surface effects, and the tubes centrifuged. Commercial wetting agents should not be used as they often interfere with the starch-iodine end point and some also contain sulphate. The supernatant liquid is poured off, the residue suspended in glycerol-water and centrifuged as before, iso-butyl alcohol again being used to prevent loss of solids on the surface. The ammonium acetate extract and washings make up group II.

The insoluble residue is suspended in 1.0 ml. of 10 per cent. sodium hydroxide solution and diluted to about 50 ml. with glycerol-water. If no sulphide is present this is group III. If sulphide is present the tubes are spun, the residue washed, and washings added to group III. The insoluble residue is group IV.

Group I.

In addition to dithionate and polythionate the solution contains a large excess of lead which must be removed. Bromthymol blue indicator is added and a suspension of sodium bicarbonate in water is slowly added with stirring until the solution becomes blue-green. The precipitated lead carbonate is filtered off and washed with aqueous alcohol. To the solution thus obtained an excess of pure sodium peroxide (0.5 g.) is added and the mixture placed in a waterbath at 80°c. for 15 minutes or longer. To decompose any peroxide remaining after oxidation is complete, 5 drops of 1 per cent. cobalt acetate is added and the solution gently boiled for a few minutes until all signs of peroxide decomposition cease. The solution is then cooled in ice-water and concentrated hydrochloric acid added until just acid to bromphenol blue. The pH should be near 2.8 which gives minimum solubility of benzidine sulphate. Benzidine reagent is now added slowly with stirring from a burette in 1 ml. portions at 2 to 3 minute intervals until the required amount has been added. The addition of 10 ml. of reagent has been found satisfactory for quantities of polythionate sulphur in the range 0.25 mg.-1.75 mg. in about 70 ml. The solution is then left in ice and water for 15 minutes and filtered through a prepared Gooch crucible. After washing with aqueous alcohol the benzidine sulphate and asbestos is suspended in about 100 ml. water. Phenol red indicator is added and the titration carried out near the boiling point with 0.02.N sodium hydroxide. Near the end point the solution is boiled for a few moments before completing the titration.

$$\text{ml. } 0.02\text{N. NaOH} \times 0.32 = \text{mg. polythionate S.}$$

The filtrate and washings from the above benzidine precipitation are made alkaline with sodium hydroxide and the alcohol distilled off. The aqueous solution is then washed with 200 ml. water into a 500 ml. three-necked flask, fitted with a dropping funnel, an inlet tube for carbon dioxide and a reflux condenser fitted at the top with a down tube dipping into 3 per cent. hydrogen peroxide, as required in the Monier-Williams method for determination of sulphur dioxide (6). A stream of carbon dioxide is passed through the flask and the contents brought to the boil. After all air is removed from the apparatus, 35 ml. concentrated hydrochloric acid, sp. gr. 1.17, (cf. Monier-Williams) are added through the dropping funnel without admitting air, and the refluxing continued for one hour. The water is then turned off and the condenser allowed to warm up, but the apparatus is disconnected just before steam enters the peroxide. The sulphuric acid formed in the peroxide is then titrated to bromphenol blue with 0.02N. sodium hydroxide. A blank determination must be carried out. As the end point is not very sharp with 0.02N. sodium hydroxide, the indicator is added to the stock peroxide solution for uniformity, and titration is carried out to a matched end point.

Recoveries of dithionate and higher polythionate (as tetrathionate) are given in Table IV.

TABLE IV. RECOVERY OF DITHIONATE AND POLYTHIONATE.

Dithionate. (mg. $H_2S_2O_6$) Added.	Recovered.	Polythionate. (mg. S) Added.	Recovered.
5.05	5.00, 5.25	0.32	0.27, 0.31
10.10	10.06, 10.10	0.65	0.60, 0.63
5.00	5.15	0.97	0.98
20.5	20.6, 20.1	1.29	1.27, 1.32
48.7	49.3, 48.7	1.62	1.64

Group II.

The ammonium acetate extract has a pH of 6. Lead salts do not affect the titration of thiosulphate, but the pH is of importance in the presence of ammonium salts. Above pH 5 the titre has been found to increase slowly up to pH 6.5 and then to increase very rapidly.

The pH of the ammonium acetate extract is brought below 5 by the addition of 10 ml. 20 per cent. V/V hydrochloric acid, starch indicator is added and the solution titrated with 0.02N. iodine.

$$\text{ml. } 0.02\text{N. Iodine} \times 2.28 = \text{mg. } H_2S_2O_3$$

A series of determinations showed that sulphate could be estimated with sufficient accuracy in the presence of ammonium acetate and lead salts. To the solution after titration of the thiosulphate, 5 ml. concentrated hydrochloric acid is added and excess of 2½ per cent. barium chloride added dropwise in the cold. The solution is set aside for one hour and the precipitate then filtered onto a weighed Gooch crucible, washed thoroughly with hot water, ignited in electric furnace at 600°c., and weighed. If lead chloride should precipitate when the concentrated hydrochloric acid is added the solution may be diluted and warmed to dissolve it, but precipitation of the barium sulphate should be carried out at room temperature.

Group III.

The alkaline extract is diluted to about 75 ml. with water containing sucrose or glycerol, and dil. hydrochloric acid added with swirling until acid to bromphenol blue. Starch indicator is added and the solution titrated with 0.02N. iodine.

$$\text{ml. } 0.02\text{N. iodine} \times 0.82 = \text{mg. } H_2SO_3$$

Group IV.

The black sulphide will be readily visible if present. In the work on sulphur dioxide there was little interest in sulphide, which could not exist in the presence of sulphite except in traces, but it was included for the sake of completeness. No mixtures were analysed for sulphide, but the results expressed in Table V. were obtained on sulphide samples which were put through the whole separation procedure. To the final precipitate of lead sulphide, finely suspended in a little water, 10 ml. of 0.02N. iodine were added, followed by 10 ml. 20 per cent. v/v hydrochloric acid. After reaction for a few minutes the mixture was diluted and back-titrated with 0.02N. thiosulphate.

TABLE V. RECOVERIES OF SULPHIDE

Sulphide present. (mg H_2S)	Sulphide recovered (mg. H_2S)
0.31	0.34
0.61	0.67
1.07	1.05
1.21	1.19
1.52	1.48

ANALYSIS OF MIXTURES

Table VI gives the results of a number of analyses of synthetic mixtures. A single solution containing all of the mentioned compounds could not be used because of chemical reaction, and the mixtures below are examples of stable combinations of standardized solutions.

APPLICATION TO PLANT EXTRACTS

It was expected that application of the method to plant extracts would present difficulties due to (1) reaction of sulphur compounds such as sulphite with the plant material, (2) interference with iodine titrations by plant materials and (3) interference with the group separation during ammonium acetate extraction. The second difficulty of necessity would have to be overcome by the use of a blank determination, and it was found that iodine-reducing plant materials were present in the ammonium acetate extract. The errors however were small and could be reduced to a very small figure by addition of potassium iodide before titration with iodine.

Reaction of sulphur dioxide with plant materials causing low recoveries had been experienced before (3), and true recoveries can only be obtained by adding sulphite to the plant material, performing a " blank " determination on this material and then carrying out the true recovery of a standard sulphite addition. The same procedure was used in the case of thiosulphate.

To test the group separation in plant materials a number of recoveries of mixtures of sulphite and thiosulphate were carried out. Some figures are presented in Table VII.

TABLE VI. ANALYSIS OF MIXTURES

	Dithionate. (mg $H_2S_2O_6$) Added.	Recovered.	Polythionate (mg S) Added.	Recovered.	Thiosulphate. (mg. $H_2S_2O_3$) Added.	Recovered	Sulphate. (mg. H_2SO_4) Added	Recovered	Sulphite. (mg H_2SO_3) Added.	Recovered.
Mixture A	10.11	10.07	—	—	2.28	2.28	—	—	5.44	5.42
„ B	—	—	—	—	4.56	4.54 ; 4.52	2.35	2.34 ; 2.14	5.30	5.28 ; 5.30
„ C	—	—	—	—	11.40	11.40 ,11.45	4.70	4.66 ; 4.63	2.12	2.10 ; 2.10
„ D	3.68	3.63 ; 3.61	1.22	1.20 , 1.23	4.56	4.51 ; 4.54	4.70	4.99	—	—
„ E	4.60	4.72 ; 4.66	—	—	2.28	2.23 ; 2.10	2.82	2.92	5.41	5.28 ; 5.25
„ F	3.68	3.48 ; 3.47	—	—	6.84	6.73 ; 6.75	4.63	4.62 ; 4.56	2.78	2.78 ; 2.67
„ G	10.11	10.10	—	—	2.28	2.21	—	—	1.09	1.10
„ H	3.68	3.55	1.83	1.77 , 1.80	6.84	6.86 , 6.95	3.80	3.90	—	—
„ I	—	—	3.05	2.98 ; 2.98	9.12	9.14 , 9.14	4.7	5.1	—	—
„ J	2.76	2.51 ; 2.50	3.05	3.04 ; 3.04	6.84	6.84 ; 6.84	3.76	3.90 ; 3.84	—	—

TABLE VII. RECOVERIES ON PLANT MATERIALS

Sample.	Thiosulphate. Added.	Thiosulphate. Recovered.	Sulphite. Added.	Sulphite. Recovered.
Potato extract (1)	Nil	Nil	4.48	4.39
,, ,, (2)	5.03	4.80	Nil	Nil
,, ,, (3)	5.03	4.62	4.48	4.69
Cabbage extract (1)	5.03	4.65	4.21	4.45
,, ,, (2)	Nil	Nil	5.15	4.95
,, ,, (3)	5.03	4.88	Nil	Nil
Carrot extract (1)	Nil	Nil	4.65	4.68
,, ,, (2)	5.03	4.80	Nil	Nil

These figures show that, as was expected, the accuracy of the method falls when it is applied to plant materials. Nevertheless use has been made of the method on plant materials with satisfactory results.

DISCUSSION

The method of analysis described above is systematic in that the components of a mixture are separated into groups in which the original compounds are unchanged. In the groups where more than one compound is present, the chemical properties are sufficiently different to prohibit interference in the quantitative determination of any one compound. Thus no errors are introduced through addition or subtraction of iodine titres on aliquots of a solution which have been subjected to a number of treatments. Although the method was intended to be used on plant materials it is felt that the method could be used with modifications in other fields. Thus in lime-sulphur spray solutions thiosulphate and sulphate can be determined readily, and the polysulphide forms a brown lead polysulphide which decomposes readily into sulphur and sulphide. This has not been investigated, but may be of use in the analysis of lime sulphur solutions.

ACKNOWLEDGMENTS

The writer wishes to thank Dr. B. W. Doak for presenting the opportunity to carry out this work, and to thank Dr. Doak and Dr. I. Reifer for their interest and helpful suggestions.

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A NOTE ON THE ADSORPTION OF QUININE FROM FLUORIMETRIC STANDARD SOLUTIONS

By L. H. BIRD, Wheat Research Institute, Christchurch.

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DURING the course of determination of thiamine in flours and wheats, the photoelectric fluorimeter used was of the twin cell balanced circuit type. This required the use of a stable fluorescing solution in one test tube to serve as a standard and also as a means of selecting for uniformity of readings the test tubes in which the unknown solutions would be compared against this standard. Quinine sulphate solutions were chosen for both purposes, and this paper describes procedures which were found to be necessary if serious errors associated with the use of quinine were to be avoided.

In an attempt to select test tubes for uniformity, a series was graded in accordance with the readings the test tubes gave when filled with a standard quinine sulphate solution. Later, when the grading was rechecked, considerable changes in the relative placings of the test tubes were observed. In addition, it was noticed that readings for some tubes tended to fall with time, towards a stable value and that this process was hastened by stirring of the solution.

Examination of the tubes giving the greatest variation showed that the surface of some had been etched and others had a slight cloudy film which resisted normal washing. These observations suggested that the discrepancies might be due to adsorption to varying degrees of quinine on the tubes. This would lower the concentration of the quinine in the solution and consequently the intensity of fluorescence. Variation in the degree of adsorption was also found when some methylene blue solution was used in place of the quinine sulphate.

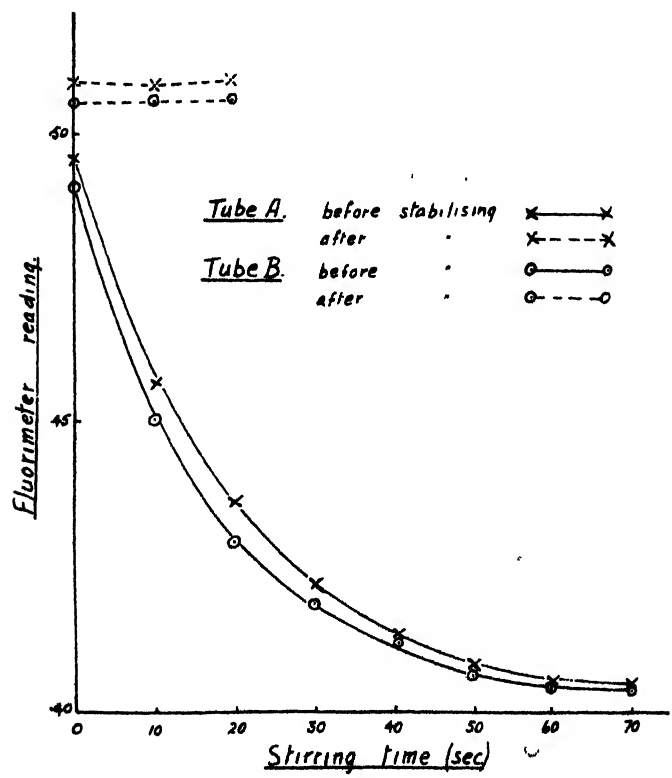

Fig. 1.—Influence of absorption on fluorescence of quinine sulphate solution.

With thiochrome solutions no evidence of adsorption could be detected, but the instability of thiochrome towards ultra-violet ruled out the use of this substance for the required standardization of the test tubes or as a reference standard.

It was considered that elimination of the problem attached to the use of the quinine sulphate as a matching solution in such tubes might be attempted in two ways: (a) by saturating the adsorptive capacity of the tubes with quinine so that no decrease due to adsorption would occur in the fluorescence of the matching solutions, and (b) by rendering the tubes non-adsorptive.

An attempt to saturate the adsorptive capacity of the tubes with quinine was made by using 10 ml. samples of a solution containing ½µg./ml. quinine sulphate in .1N sulphuric acid in the tubes. After taking readings in the fluorimeter against a stable solution containing 1µg./ml. quinine sulphate in .1N. sulphuric acid, these solutions were subjected to repeated stirrings (each of 10 sec. duration) by means of a glass rod mounted in an electric laboratory stirrer, until no further drop in fluorescence was observed. After stability had been reached these solutions were discarded and the tubes refilled with fresh solution. Readings were again taken before and after stirring, typical results being given in Fig. 1.

The results obtained showed that the tubes had been successfully stabilized by saturation with quinine and also that the drop in fluorescence of the quinine sulphate solutions in the adsorptive tubes was appreciable even over the short interval of time which elapsed prior to taking the initial readings.

On the results obtained with the stabilized tubes, several sets of tubes giving closely similar readings were selected and finally checked with portions of a thiochrome solution. The efficiency of the saturation treatment in enabling the selection of tubes with uniform characteristics is shown by the following readings obtained with thiochrome solutions in one set of twelve tubes:—

Tube No.	Fluorimeter reading	Tube No.	Fluorimeter reading.
1	.447	7	.446
2	.446	8	.448
3	.446	9	.447
4	.447	10	.447
5	.447	11	.446
6	.448	12	.446

While a selected set of tubes would continue to give good agreement with thiochrome solutions, it was found that after repeated use they would develop strong adsorption towards quinine sulphate, thus making any subsequent recheck with this material useless unless the tubes were again stabilized.

Work was carried out later in an endeavour to find a treatment which would render the tubes non-adsorptive. It was found that if a 30 per cent. solution of sodium hydroxide was maintained at boiling point for approximately one minute in highly adsorptive test tubes, these would, after washing and drying, show no further adsorption of either quinine sulphate or methylene blue.

A set of tubes from a batch known to be strongly adsorptive was treated with hot alkali and after washing and drying was checked with quinine sulphate solution. The results given below for two typical tubes show that the treatment was effective:

Tube.	Initial reading.	After stirring.
C	.503	.504
D	.500	.500

Since the completion of the above investigation, a new consignment of test tubes has been checked and found to have negligible adsorption.

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